UTILISATION OF PORK RIND AND SOYA PROTEIN IN THE PRODUCTION OF POLONY

by

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SUMMARY

The purpose of this study was to determine whether acceptable polony can be manufactured with varying quantities of chicken mechanically recovered meat (MRM), soya flour and pork rind to a fixed protein content of 10%, irrespective of fat content and without the addition of more fat to obtain a total meat equivalent (TME) of 75%. The effect of replacing MRM with soya and rind on the chemical, physical and sensory characteristics of polony was measured. The cost of producing each treatment by using the varying ingredients was also calculated.

Three levels of soya flour (0, 4 and 8%) were combined with three levels of pork rind (0, 8 and 16%) to formulate the nine treatments of polony (R0S0, R0S4, R0S8, R8S0, R8S4, R8S8, R16S0, R16S4 and R16S8, where R and S represents rind and soya, respectively). The cost of making the nine treatments varied from R4.54/kg to R2.91/kg, where the most expensive treatment was the one in which no replacement of MRM was done (R0S0) and the least expensive treatment was R16S8, where most MRM was substituted with rind (16%) and soya (8%). The chemical results showed that the protein content of the nine treatments varied between 9.7 and 10.5%. Fat and ash decreased while moisture and total collagen increased as more MRM was being replaced with increasing levels of soya, rind or combinations of them.

The physical results indicated that L* and b* increased while a* decreased, resulting in treatment samples which were lighter, more yellow and less red in colour. Hardness and gumminess increased in samples singly replaced with 8% rind, 4% soya or their combination (R0S0, R0S4, R8S0 and R8S4), while they decreased in the rest of the treatments. Cohesiveness increased in all treatments with increasing levels of soya and rind except for the sample containing 16% rind and 8% soya (R16S8). The pH of treatments containing 0% soya increased with rind increase whereas those with 4% soya did not change. The lowest pH was for the sample with 16% rind and 8% soya (R16S8). Sliceability was used to determine the ease of cutting intact slices at slice thicknesses of 2 and 3 mm. The sliceability of polony treatments which exhibited good slicing characteristic ranged between 80 and 100% at both 2 mm and 3 mm slice thicknesses. Sliceability was poorest for the treatment with high levels of rind and soya (R16S8) at both 3 mm (40%) and 2 mm (0%). The water holding capacity (WHC) of all treatments improved, except for the treatments to which no rind and soya was added (R0S0) and the treatment in which MRM was replaced with 8% soya (R0S8).

Sensory analyses results signified that pink colour, colour intensity, salty taste, flavours (garlic, polony and spicy) and firmness decreased while soya flavour, pasty and fatty mouthfeel increased with increasing levels of rind, soya or their combination. Coarse texture decreased as rind increased while it increased with an increase in soya levels. Only five treatments were employed for consumer analyses. The most preferred treatment was that with 0% rind and 0% soya (R0S0), while the sample with 0% rind and 8% soya (R0S8) was the least preferred. It can be concluded that the production of polony through the replacement of MRM with rind and soya flour is possible, but consumer preference results show that consumers like polony products which have low levels of soya (≤4%) and moderate levels of rind (≤8%). However, the negative effects of rind and soya in polony with high levels of soya and rind can be rectified by adding appropriate additives, as provided for by manufactured meat regulations.

OPSOMMING

Die doel van hierdie studie was om vas te stel of wisselende hoeveelhede meganies herwonne hoendervleis, sojameel en swoerd gebruik kan word om aanvaarbare polonie te vervaardig met ’n vaste proteïeninhoud van 10%, ongeag die vetinhoud, en sonder die byvoeging van meer vet om ’n algehele vleisekwivalent van 75% te kry. Hiervoor is die uitwerking op die chemiese, fisiese en sintuiglike kenmerke van polonie gemeet wanneer meganies herwonne vleis (“mechanically recovered meat”, oftewel “MRM”) met soja en swoerd vervang word. Voorts is die produksiekoste van elke formule op grond van verskillende bestanddele bereken.

Drie vlakke sojameel (0%, 4% en 8%) is met drie vlakke swoerd (0%, 8% en 16%) gekombineer om die nege polonieformules (R0S0, R0S4, R0S8, R8S0, R8S4, R8S8, R16S0, R16S4 en R16S8) te skep, waar R die swoerd (“rind”) en S die sojameel verteenwoordig. Die vervaardigingskoste van die nege formules wissel van R4,54/kg tot R2,91/kg: Die duurste formule was dié sonder enige MRM-vervanging (R0S0), en die goedkoopste waar die meeste MRM met swoerd en soja vervang is (R16S8). Die chemiese resultate toon dat die proteïninhoud vir die nege formules tussen 9,7% en 10,5% wissel. Vet en as het afgeneem en vog en algehele kollageen het toegeneem namate al hoe meer MRM met toenemende vlakke soja, swoerd of ’n kombinasie daarvan vervang is.

Fisiese resultate toon dat L* en b* met MRM-vervanging toegeneem het, terwyl a* afgeneem het, met ligter, geler en minder rooi monsters tot gevolg. Hardheid en taaiheid het toegeneem by monsters waar MRM stuksgewys met 8% swoerd, 4% soja of ’n kombinasie daarvan vervang is (R0S0, R0S4, R8S0 en R8S4), terwyl dit by die res van die formules afgeneem het. Saamklewing het by alle formules met hoër vlakke soja en swoerd toegeneem, buiten by die monster met 16% swoerd en 8% soja (R16S8). Die pH van formules met 0% soja het toegeneem namate die swoerd vermeerder is, terwyl dié met 4% soja onveranderd gebly het. Die laagste pH is aangeteken by die monster met 16% swoerd en 8% soja (R16S8). Snybaarheid is bepaal aan die hand van die gemak waarmee skywe van onderskeidelik 2 mm en 3 mm dik gesny kon word. Goeie snybaarheid, met ander woorde tussen 80% en 100%, is aangeteken vir polonie wat in sowel 2 mm as 3 mm diktes gesny kon word. Snybaarheid was die swakste vir die formule met hoë vlakke swoerd en soja (R16S8), vir sowel die 3 mm (40%) as die 2 mm diktes (0%). Die waterhouvermoë het by alle formules verbeter, buiten by die formule waarby geen swoerd of soja gevoeg is nie (R0S0) en die formule waar MRM met 8% soja vervang is (R0S8).

Die resultate van die sintuiglike ontledings dui daarop dat die pienk kleur, kleurdiepte, sout smaak, geure (knoffel, polonie en speserye) en fermheid afgeneem het, en die sojageur, deegagtige tekstuur sowel as die tekstuur op die tong toegeneem het namate meer swoerd, soja of ’n kombinasie daarvan bygevoeg is. Grofheid van tekstuur het afgeneem namate die swoerd verminder is, terwyl dit weer toegeneem het met ’n toename in soja. Slegs vyf formules is vir verbruikersontledings gebruik. Die gewildste formule was dié met 0% swoerd en 0% soja (R0S0), terwyl die monster met 0% swoerd en 8% soja (R0S8) die minste byval gevind het. Daar kan dus afgelei word dat polonieproduksie deur die vervanging van MRM met swoerd en sojameel moontlik is, hoewel die proetoetsresultate toon dat verbruikers polonieprodukte met lae sojavlakke (≤4%) en matige swoerdvlakke (≤8%) verkies. Tog kan die negatiewe uitwerking van groot hoeveelhede swoerd en soja in polonie reggestel word deur toepaslike bymiddels, waarvoor die regulasies oor verwerkte vleis voorsiening maak, by te voeg.

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NOTES

The language and style used in this thesis are in accordance with the requirements of the scientific journal, *International Journal of Food Science and Technology*. This thesis represents a compilation of manuscripts where each chapter is an individual entity and some repetition between the chapters has therefore been unavoidable.

CHAPTER 1

INTRODUCTION

Sausages are popular meat products enjoyed by millions of consumers world-wide (Giese, 1996; Huffman & Egbert, 1990; Mendoza *et al*., 2001). Several types of sausages are available on the South African market. One of the groups of sausages which are very popular is that of emulsified sausages. Emulsified sausages are different from other sausages due to the fact that they are finely ground (Marianski *et al*., 2007). Polony is an example of a finely emulsified sausage. Polony is a large-diameter sausage formed from changing coarse heterogeneous meat into a homogenous meat mass in which are dispersed water, fat and protein, that during heating is transformed into a gel (Giese, 1992). Others are bologna, frankfurters mortadella and frankfurters (Pomeranzi, 1991). Mortadella is a large smooth smoked sausage of Italian origin which is prepared from pork fat, garlic, pistachios , cardamom, cloves, salt and pepper (Ahmad, 2005). Bologna is also a large, smooth-textured smoked sausage of beef, veal and pork. Bologna is similar to mortadella but it is an American sausage. Frankfurters are small diameter, fully cooked or smoked sausages made from pork, beef and chicken (Nurul *et al*., 2010). Among the emulsified sausages, polony was used as experimental units in this research. There is no special reason why polony was chosen for use in the current study, apart from the fact that it is one of the common emulsified sausages in South Africa. Typical emulsified sausages contain 20 to 30% fat, which contributes to the energy, textural and organoleptical characteristics of the product (Candogan & Kolsarici, 2003; McKeith *et al*., 1995). One of the reasons why consumers today consume sausages is due to their nutritional value (Pearson & Tauber, 1984). Since sausages are meat based products, they are regarded as an excellent source of protein and energy in the human diet (Quaem *et al*., 2009). Meat protein is complete, containing all the nine essential amino acids (Gibis *et al*., 2010). Essential amino acids cannot be synthesised by the human body. For that reason, essential amino acids have to be supplied to the human body by consuming foods which contain them (Feiner, 2006). Meat and sausages are also good sources of B complex vitamins, and all minerals except calcium. However, calcium could be slightly higher in sausages if mechanically recovered meat (MRM) is used as a protein source. This is because bones are crushed together with the meat, resulting in the extraction of some bone calcium along with meat during the recovery of meat from the frame of an animal. According to the South African National Standards (SANS 885) of 2003, MRM is pulped material that consists predominantly of musculature tissue, collagen, marrow and fat, and that has been recovered by a process of mechanical separation from bone.

In spite of their excellent high quality proteins, meat and meat products are often too expensive for poorer communities needing suitable dietary protein (Whitney & Rolfes, 1999). According to Gorbatov (1988), the mental ability of children, the health and capacity for work of adults depend on the quantity and quality of the protein in the diet. Animal protein has been found to meet these human needs because they contain all essential amino acids and are better assimilated than most plant proteins. In order to provide more affordable, high quality protein products, the strategy which is widely used is the partial replacement of the lean meat with non-meat ingredients. Both extenders and fillers are often used. Extenders such as soya isolate, soya concentrates, milk powder, whey powder and egg white are often used. Extenders which are used in sausage formulations are characterised by high protein content (Aberle *et al*., 2001; Varnam & Sutherland,1995). Fillers are usually carbohydrate materials such as carrageenan and various starch materials (Subba, 1998). Apart from reducing the cost of producing sausages, extenders and fillers increase

bulkiness, binding of the meat matrix and water holding capacity. In order to make polony cost effective, the extenders and fillers which are used for substitution should be relatively cheaper than lean meat (Varnam & Sutherland, 1995).

Soya protein is frequently used as a replacer of meat protein due to its essential amino acid composition, which is not very different from that of meat. Soya protein also functions as a binder of polony gel and contributes to water holding and the emulsification of fat (Akesowan, 2008). In the West, interest in and consumption of soybeans has increased following recent medical investigations of the health benefits of soybeans. Soya protein has been found to lower blood serum cholesterol in high cholesterol individuals and it decreases the risk of coronary heart disease. Soya protein can also decrease the incidence of breast and prostate cancer and inhibit bone resorption, partially because of the presence of isoflavones (Lee & Brennand, 2005). In the present study, locally processed, deflavoured soya was used. The cost per kg protein derived from soya is usually less than that derived from animal proteins. Besides soya flour, pork rind was also used to partially replace meat. Pork rind, also called pork skin, is normally added to the formulation because it contributes to the total meat content as well as to the binding of water and fat in the sausage emulsion (Yada, 2004; Ranken, 2000).

However, prior to any substitution, it is highly recommended that regulations on various processed meat products should be consulted. The latest labelling regulations in South Africa (R146 under Act 54 of 1972, administered by the Department of Health) refer to a National Standard (SANS 885) for the definitions of processed meats. SANS 885 stipulates the following (Table 1):

Table 1 Definitions of the components of emulsified meat products.

Ingredient	Percentage
Minimum total meat	35%
Maximum edible offal	15%
Maximum fat	30%
Minimum [(protein x 4.8) + fat]	75%
Minimum protein	9.4%

(Examples are polony, vienna sausages, frankfurters and meat loaves without any visible coarse ingredients)

SANS 885 further stipulates that the actual total meat content should be at least 35%, where this (total meat) is defined as**:**

"total meat per cent – which is lean meat (including mechanically recovered meat, except where the latter is specifically excluded), per cent, plus fat, per cent. Total meat is the quantity going into the mix."

Pork rind is defined as meat in the following quotation:

"meat – is sound skeletal musculature, excluding the musculature of the lips, snout, scalp and ears, of healthy food animals, with or without connective tissue, blood vessels, lymphatic and nerve tissue, bone, fat, cartilage, scraped skin (pigs), and defeathered skin (poultry) that are naturally associated with such musculature *in situ* in the dressed carcass and head."

This is in contradiction to the definition of edible offal, where the rind is again defined as edible offal:

"edible offal – In the case of food animals other than poultry: blood, blood plasma, brain, cow-heels, diaphragm, gut (casings), washed head, kidneys, omentum, pancreas, pluck (oesophagus, trachea, lungs), heart, pericardium, associated lymph nodes, pillars of the diaphragm and liver or part thereof (without the gall bladder), rind and skin, spleen, tail, thymus, tongue, cleaned tripe, trotters and udder (in the case of a heifer)."

Since the definition of meat specifically refers to scraped skins of pigs as "meat" when present in a ratio naturally found *in situ*, it may be the intention of the definition of edible offal to exclude pork skins under the term "rind and skin" as in the definition of "edible offal". The amount of skin found *in situ* is arguable and may be open to interpretation. Generally, pork skin is used to a large extent in the South African meat processing industry as "meat", depending on its availability.

These discrepancies were considered in the present study. It was decided to formulate all products to have 10% protein content, irrespective of the source of protein, although, by definition of emulsified sausages, the minimum required protein is only 9.4%, which, when multiplied by 4.8, is equivalent to 45.12% lean meat (LME, or lean meat equivalent). At this level of LME (45%), one has to include the maximum permitted amount of 30% fat to obtain a total of 75% for % LME + % fat. Due to the negative health aspects associated with fat intake, it was further argued that the fat content would not be increased to yield a total of 75% total meat (TME, or total meat equivalent) in the present study. At a level of at least 10% protein content such meat products may then be referred to as "high in protein" (Department of Health, 2010), whereas a minimum of 9.4% protein would not qualify for such a claim.

The purpose of this study was to determine whether acceptable polony can be manufactured with varying quantities of chicken MRM, soya flour and pork rind to a fixed protein content of 10%, irrespective of fat content and without the addition of more fat to obtain a TME percentage of 75%. The acceptability was measured and judged by various methods, while the chemical composition of each treatment is also reported.

For this study, three levels of soya flour inclusion (0%, 4% and 8%) were used with three levels of pork rind inclusion (0%, 8% and 16%) in an incomplete factorial design. In order to maintain 10% protein content throughout the trial, the MRM and water were adjusted for each of the nine formulations. The nine combinations or treatments of polony which were made were R0S0, R0S4, R0S4, R8S0, R8S4, R8S8, R16S0, R16S4 and R16S8, where R and S represent pork rind and soya flour, respectively. In South Africa, levels of up to 8% soya inclusion is common practice, as is the inclusion of up to 16% pork rind.

It should be noted that, whether pork rind is "meat" or "edible offal", the maximum inclusion level was 16%, while the national standards permits the use of edible offal to an inclusion level of 15% (SANS 885, 2003). It should further be noted that the fat contents of the final products is purely dependent on the fat content of the raw materials used for each treatment, and was not manipulated.

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CHAPTER 2

LITERATURE REVIEW

1. INTRODUCTION

Several varieties of polony products are sold in South African supermarkets. Examples of such products are chicken polony, beef polony, garlic polony, lamb polony and masala polony. The factor which is largely responsible for driving the production of assorted polony products is the consumer demand for safe, convenient and unique flavours (Aberle *et al*., 2001; Hui *et al*., 2001). One of the reasons which has led to increased production and consumption of convenient foods such as polony in the past two decades has been the increased awareness of the need to have adequate protein intake for healthy living (Bhaskar *et al*., 2009). Polony is convenient because it is a fully cooked sausage, and therefore it can be consumed without cooking (Estes *et al*., 1982). For this reason it reduces on domestic labour associated with preparation and cooking. This is particularly common among people who are facing the pressure of work (Pearson & Tauber, 1984).

Although every manufacturer has its own closely-guarded formulae and techniques for making sausage, there are general procedures which all manufacturers use (http://www.usdec.org). In general, sausages are comminuted and usually spiced or seasoned to obtain various flavour profiles. Besides spices and the seasoning ingredients, meat is also used in the processing of most sausages, polony inclusive. For this reason, the proper selection of meat ingredients is essential for the production of sausages of uniform quality. Commonly, the raw meats used for sausages are low-value materials, but they must be fresh with low microbial counts. These include cuts high in connective tissues or fat, tough meat from mature animals, carcass trimmings, mechanically separated/recovered meat (MRM) and edible animal by-products. The function of each selected raw meat ingredient may be unique. For instance, meat for binding the sausage matrix should have sufficiently high protein content and the proteins should be readily extracted and form gels during cooking (Hui *et al*., 2001). In the manufacture of polony, beef, veal and pork are usually used (Giese, 1992). Apart from these traditional meat ingredients, MRM from chicken is also widely used as a protein source in the production of polony and other sausages. Proteins of meat, regardless of the source, are highly valuable nutritionally and also technologically (Heinz & Hautzinger, 2007). The product preparation and behaviour during processing and cooking depend on the functionality of the meat soluble proteins of the myofibril (Mourtzinos & Kiosseoglou, 2005). Meat proteins also influence other basic functional properties of meat products such as water binding, fat binding and gel-forming capacity. All these properties are as a result of protein-water, protein-lipid and protein-protein interactions. Typical commercial products of meat emulsions contain 12% protein and 30% fat (Matulis *et al*., 1995; Barbut, 1995).

Due to the importance of proteins, this chapter reviews the processing of polony, including the role of extracted and non-meat proteins in processing, and of course not forgetting the functions of non-protein additives. The methods used for measuring the effects of denatured protein on polony are also discussed. Lastly, the regulations governing polony processing in southern Africa, particularly in Zambia and South Africa, are reviewed.

2. POLONY PROCESSING

Feiner (2006) and Hui *et al*. (2001) outline the common steps which are used for manufacturing cooked sausages as well as other sausages. Some of these steps can be applied to polony processing. The steps are emulsification, filling, smoking, and cooking and cooling of the meat product.

2.1 Emulsification

Emulsification involves an extensive chopping (comminution) of meat to produce small particles. Generally, there are three different systems which are used to emulsify meat in the production of emulsified sausages. One uses only the bowl cutter, the second uses a bowl cutter and an emulsifier, and the third uses a mixer-blender system. The first two are used in batch or non-continuous production processes while the last one is used for large-volume production (Feiner, 2006). A bowl cutter is a machine in which cutting takes place in a circular, curved and slowly rotating bowl. The meat and fat mass is carried anticlockwise towards a set of rapidly rotating knives. At least six knives should be used for manufacturing cooked sausages (Feiner, 2006). During the cutting process, most of the proteins are extracted or activated by destroying large amounts of sarcolemma, transforming the heterogeneous mass of lean meat and fat into a homogenous paste-like mass called meat batter (Feiner, 2006; Foegeding, 1988). Additives such as salt, nitrites and phosphates, in conjunction with water (ice) added at this stage, start to solubilise myosin and actin by turning these fibrous proteins into a liquefied material (Feiner, 2006). After a period of cutting and solubilising, the viscosity of the sausage mass increases and, as the temperature rises to 4 – 6°C shearing forces increasingly come into play. From this stage onwards, the protein is activated by shearing forces rather than by cutting (Feiner, 2006) until the sausage batter is fully emulsified. Meat batters are fluid and primarily composed of water, fat and protein (Foegeding, 1988). In the meat industry, sausage batter or emulsion is defined as the finely chopped mixture of lean meat, fat, spices and ice, depending upon particle size (Pearsons & Gillet, 1996; Morrin *et al*., 2004).

2.2. Role of additives in polony processing

Salt (sodium chloride), as patented by Hubert *et al.* (1983), has at least three primary functions in the manufacture of sausages. Firstly, it dissolves in water to form brine, which acts to retard microbiological growth. Secondly, it contributes to the basic taste characteristics of sausages. Thirdly, it aids in solubilising the myosin protein of comminuted animal muscle so as to enable emulsification of the fat by the swollen protein. The solubilised myofibrillar proteins (myosin and actin) form a film or layer around fats which are dispersed in water. This interaction of protein with fat and water is essential for stabilising the meat emulsion. It also prevents the coalescence of fat particles (Feiner, 2006). The stabilising effect prevents excessive loss of fat and water during cooking (Foegeding, 1988). The emulsified sausages are called meat emulsions because their structure comprises fats (dispersed phase) in a protein-water solution (continuous phase). Technically, however, sausages are not true oil-in-water emulsions, as neither phase is a liquid (Pearsons & Gillet, 1996; Morrin *et al*., 2004).

The nitrite salt is indispensable in meat curing and no substitute has been found yet. Sodium nitrite is a toxic substance and can be fatal even in small doses. A single dose of nitrite in excess of 15 to 20 mg/kg of body weight can be lethal. Under certain conditions (high temperature and low pH), a class of carcinogenic

compounds known as nitrosamines can be formed in meat products by reactions between nitric oxide and secondary or tertiary amines. To reduce the toxicity of the nitrite, very small quantities are mixed with common salt at a concentration of about 0.6% nitrite and 99.4% common salt to form the nitrite salt. The maximum amount of nitrite permitted in finished meat products is usually 200 ppm (Aberle *et al*., 2001). The primary function of nitrite is the production of the characteristic pink colour of cured meats, which is desired by the consumer and is usually indicative of the quality of cooked products (Shahidi & Pegg, 1991). By virtue of its strong antioxidant properties in meats, nitrite also inhibits lipid oxidation and contributes to desirable meat product flavour (Sanz *et al*., 1997). The formation of the pink colour is a result of the conversion of the nitrite to nitric oxide (NO), which subsequently reacts with myoglobin to form nitrosylmyoglobin. The nitric oxide myoglobin (nitrosylmyoglobin) has a bright, attractive colour which is stabilised by heating. The resulting colour after heat treatment is nitrosylhemochromogen, which is responsible for the bright pink characteristic of cured meat (Aberle *et al*., 2001). The nitrite also inhibits the growth of spoilage and pathogenic bacteria such as *Clostridium botulinum* (Marco *et al*., 2006; Flores & Toldrá, 1993). In order to speed the formation of nitrosylmyoglobin, ascorbic acid is added. Ascorbic acid is a strong reducing agent. Ascorbic acid must not be added to, or mixed with, nitrites, because it can instantly break down the nitrite, thus rendering it useless for curing. The nitrite must be added at the beginning of curing, whereas ascorbic acid is always added at the end of comminution. Ascorbic acid is used in concentrations ranging from 0.03 to 0.05% (FAO Technical Paper, 1991).

The phosphates are used in meat products for several reasons. The principle reason is increased yields, which are accomplished by raising the pH of the meat protein, which in turn allows the protein to hold more water. Most phosphates are sodium based, but potassium phosphate is also available. The most commonly used phosphate is sodium tripolyphosphate (STP). This phosphate is the most alkaline, produces the highest yield and is the most economical. One should be cautious with high phosphate levels in high fat products, because fat and phosphate make soap, which could negate consumer acceptance of the sausage (Nassau Foods, 2008).

A few minutes after the addition of the sodium chloride, nitrites and phosphate salts, water is added to the mixture of ingredients during comminution. If frozen meat is used in polony production, water is used, while ice is used if the meat is thawed before processing commences (Feiner, 2006). The water solubilises the salts and water-soluble proteins. It also helps to control the temperature of the meat batter. Normally the temperature should be between -1 and 3°C after the addition of water. Around this temperature the non-meat ingredients and spices are added, followed by adding some water again. Starch is the last ingredient to be added because it raises the temperature of the batter due to the high shear forces generated during comminution. The temperature may rise to 12°C and should never go beyond 18°C, as the proteins required for emulsification could be denatured at high temperatures.

Spices are aromatic substances derived from vegetative plants or herbs. Various parts of the plant are used to produce different spices. For example, cloves come from the flower bud, nutmeg and pepper from the fruit, mace from the aril (external fleshy covering of the seed), cinnamon from the bark of the tree, and ginger from the rhizome or underground stem. Cardamom, coriander and mustard are derived from aromatic seeds. The aromatic properties of the spices are found in the volatile oils and oleoresins. The oleoresins include the volatile oils in combination with the plant resins. Spices are used in sausages for their aroma and flavour. As a result of the high concentrations of flavour that spices contribute to sausages, there

is need to control how much is used in formulations. Besides contributing to flavour, spices in some instances also exhibit bacteriostatic and antioxidant actions (Pearson & Tauber, 1984). Herbs are the dried leaves of plants, and those used in sausages include sage, savory, thyme and marjoram. Seasonings originating from vegetable bulbs are onion and garlic (Aberle *et al*., 2001). All the above chemicals are added in their specific order during the chopping or emulsification stage. The next step after emulsification is filling the meat batter into packaging materials.

2.3. Filling

Filling is a process in which the emulsified raw sausage mass is filled into packaging materials called casings. As soon as the sausage batter is ready, it must be packaged to prevent it from souring. Souring makes the taste and flavour of the sausage unacceptable and impairs the binding in the emulsion owing to the drop in pH, which reduces water holding capacity. Ideally, a vacuum should be applied during filling to prevent air pockets, as they affect the firmness, colour and stability of the final product, as well as increase the risk of fat and water separation within the air pockets themselves. The colour in air pockets quickly changes from red to green or grey during storage of the finished product (Feiner, 2006).

Cooked sausages are filled into natural casings, such as sheep and hog casings, as well as large natural casings from cattle such as bungs. Most large diameter cooked sausages are filled into water-proof casings to avoid product leaching during cooking. Large-diameter products should be filled horizontally and straight, as any redirection of the sausage mass during filling applies mechanical forces, which increase the risk of fat and water separation (Feiner, 2006). All cooked sausages should be filled firmly into the respective casings. Filling the product too loosely affects the firmness of the finished product and could result in wrinkling. Filling the products tightly into waterproof casings also helps to minimise the risk of fat or water separation during thermal treatment (Feiner, 2006). After filling, the polony is smoked (optional) and then cooked.

2.4. Smoking and cooking

The smoking and heating of processed meats can be considered as two separate processing steps. They are discussed together, as the two processes occur simultaneously or in immediate succession in some products. Most products are both smoked and cooked (frankfurters and bologna). However, a few products are only smoked with a minimum of heating (mettwurst and some Polish sausages), while others are cooked but not smoked (liver sausages) (Aberle *et al*., 2001). Smoking of meat is the process of exposing products to wood smoke at some point during manufacture. Smoking methods originated simply as a result of meat being dried over wood fires. The development of specific flavours and the improvement of appearance are the main reasons for smoking meat. The other reason for smoking is to impart some preservative effects to meat products. More than 700 compounds have been identified in wood smoke. Some of them are classic alcohols, ketones, carboxylic acids, heterocyclic hydrocarbons, sulphur-containing organic compounds, phenols and terpenoids. Although many of these compounds exhibit either bacteriostatic or bactericidal properties, formaldehyde accounts for most of the preservative action of smoke. In addition, phenols have an antioxidant activity. Various combinations of these compounds in wood smoke contribute to the flavour and aroma of smoked meats. The heterocyclic hydrocarbons have a catalytic effect on the carbonyl-amine browning reactions, which contributes to the colour and sensory properties of smoked meat products (Aberle *et al*., 2001).

Typical heat-processed meat products are cooked until an internal temperature of 65 to 77°C is reached. Temperatures in this range are sufficient to kill most of the microorganisms present, including *Trichinella spiralis*, a parasite which causes trichinolosis and is occasionally found in pork. For this reason the thermal treatment of cooked sausages pasteurises and preserves the meat products. In addition to pasteurisation, other important changes result from the heating process. Of special significance is the firming of product texture resulting from protein gelation. The proteins that were solubilised during meat batter formulation, and those remaining in the myofibrillar structures, undergo a dynamic process of unfolding (denaturation) and aggregation (coagulation) during heating (Aberle *et al*., 2001). The denaturation, aggregation and cross-linking of some specific proteins (which were used in this project), such as chicken MRM chicken, soya and pork rind are discussed in the sections which follow. The gelatinisation of non-protein ingredients such as tapioca starch is also discussed.

2.5. Cooling of sausages

Once the target core temperature of the cooked sausage has been reached, the products are removed from the cooking chamber for cooling. There are two types of cooling methods: continuous showering and interval showering. In continuous showering, there is a continuous supply of cold water into the cooling tank to prevent the temperature from rising. In interval cooling, showering is done in intervals so as to give a chance for heat to move from the core of the product to the outer part of the sausages. Generally, the showering time varies and depends on the diameter of the meat product. Sausages in natural casings are showered with cold water for around 15 to 30 min. If the product is not sufficiently showered with cold water, it will become wrinkled during storage, because the warm sausage mass will continue to shrink with the casing. After showering, the sausages are cooled quickly, usually in a blast chiller, down to a temperature below 4°C to prevent bacterial growth (Feiner, 2006).

3. MECHANICALLY RECOVERED MEAT (MRM) OF CHICKEN

According to the South African National Standards (SANS 885) of 2003, MRM is pulped material that consists predominantly of musculature tissue, collagen, marrow and fat, and that has been recovered by a process of mechanical separation from bone. Historically, the technology of removing meat from bones or fat started in Japan in the late 1940s. The first recovered meat involved removal of fish meat from the bones of filleted fish. The mechanical recovery of poultry from backs, necks and other bones with meat attached started in the late 1950s. The number of machines increased as the number of cut up chicken and turkey increased. This indicates that this technology developed with an objective of preventing the wastage of essential meat proteins on frames. The removal of beef and pork from irregularly shaped bones began in the 1970s. The vertebral column and other bones with meat still attached after hand trimming were used (Kolsarici *et al*., 2001; Froning, 1981; Barbut *et al*., 1985).

MRM is a typical industrial product and is not produced in small operations. However, it is available on the meat market and can be purchased by smaller producers as frozen blocks for further processing (Heinz & Hautzinger, 2007). Mechanically deboned poultry meat is frequently used in the formulation of comminuted meat products due to its fine consistency and relatively low cost for partial substitution of the lean meat (Crosland *et al*., 1995; Heinz & Hautzinger, 2007). However, MRM addition is limited, as high amounts will affect the quality of products (leading to poor texture and taste) and may in some countries result in products which are not in line with national food regulations (Heinz & Hautzinger, 2007).

The composition and storage stability of the final product of MRM is affected by the raw materials and conditions used for mechanical deboning (Crosland *et al*., 1995). Mechanical deboning results in cellular disruption, protein denaturation, and increased lipid and haem oxidation (Kolsarici *et al*., 2001). Mechanically deboning of poultry affects the proximate composition of the resultant meat. The considerable amounts of lipids present in the raw material are incorporated in the MRM, diluting the protein and increasing the lipid content of the deboned tissues. These lipids include those present in the bone marrow, subcutaneous fat and skin (Trindade *et al.,* 2004). The composition of chicken MRM from various parts of the chicken has been reported by several researchers (Table 1).

Table 1 Average proximate, hydroxyproline and collagen (as %) composition of chicken meat.

Proteins	Fat	Moisture	Ash	Hydroxyproline	*Collagen	References
11.9 – 16.7	13.8 – 22.0	66.6 – 70.0				Hamm & Searchy (1981)
14.4	13.4	72.2				Essary (1979)
14.9 ± 0.40	8.6 ± 0.73	74.9 ± 0.15	1.3 ± 0.01	0.26 ± 0.02	2.08	Tanaka & Shomokomaki (1996)

*Collagen = hydroxyproline x 8 (Kolar, 1990)

3.1. Structure of poultry muscle tissue

The muscle tissue from which MRM is derived is considered the most important in terms of poultry meat processing. The muscle of poultry is composed of numerous muscle bundles which are covered by the epimysium, as shown in Figure 1. Each muscle bundle is separated from the others by a connective tissue called perimysium. The connective tissue is important in providing structural organisation, anchoring the different components and transmitting the power generated by the contraction of the small muscle units called the sarcomeres. The muscle bundle is composed of smaller muscle fibers that are covered by a thinner layer of connective tissue called endomysium. Each fibres consists of numerous myofibrils that have myofilaments inside of them. The myofibril's striated appearance is the result of the repetitive structure of overlapping thin and thick filaments (Barbut, 2001).

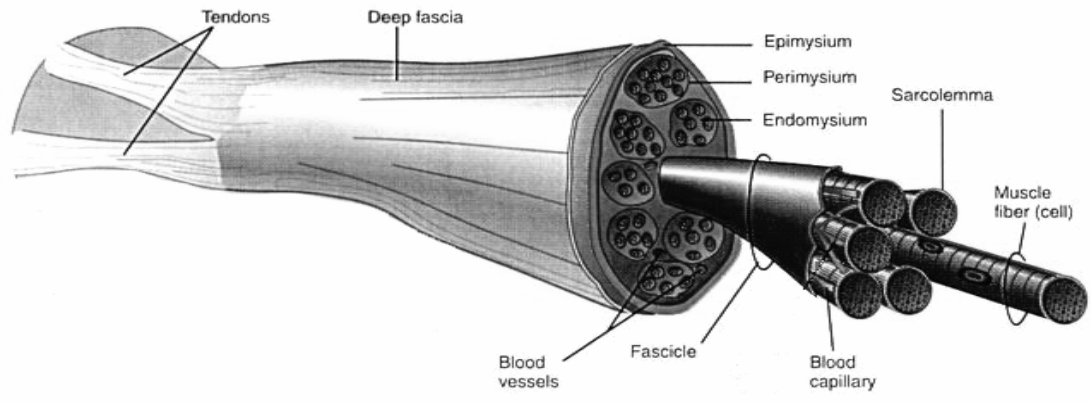


Figure 1 Assembly of muscle. Modified from the images at http://faculty.etsu.edu/currie/images/. Accessed 28 March, 2010.

3.2. Muscle protein

Each muscle structure is essentially built of proteins. Proteins comprises of 18 to 20% of the lean muscle weight, whereas water and fat represent about 75% and 5% respectively. Muscle proteins can be divided into three major groups based on their water and salt solubility (Barbut, 2001). These groups are sarcoplasmic, myofibrillar and stromal proteins. They make up approximately 35, 60 and 15%, of total proteins in the muscle tissue respectively (Yada, 2004; Lametsch & Bendixen, 2001).

The sarcoplasmic protein fraction (found in the sarcoplasm) consists of at least 500 individual proteins, including many metabolic enzymes, and they are soluble in water and diluted salt solution (ionic strength of 0 to 0.2 M) (Pearson & Young, 1989). Most sarcoplasmic proteins are of a globular structure with a high density of exposed polar charged side chains. Myoglobin protein is probably the best known member of this family because of its prominent role as the chief pigmentation protein in fresh meat.

The myofibrillar proteins are soluble in a salt solution of 2% or ionic strength of more than 0.5 M, and are responsible for much of the functional characteristics of fresh and processed muscle foods. Myosin and actin are the most important constituents of myofibrils and account for more than 70% of myofibrillar protein (Pearson & Young, 1989).

Stromal proteins are soluble only in acid or alkaline solutions, but can be solubilised with slow, moist cooking in the absence of acid and alkali compounds. They are mostly located in the interstitial space of the muscle cells and are generally referred to as connective tissue proteins (collagen, reticulin and elastin) (Pearson & Young, 1989). These proteins are the major constituents in endomysium, perimysium and epimysium. At least ten genetic types of collagen have been identified in meat animals. Type I and III are the major components of intramuscular collagen and of the greatest relevance when discussing meat texture (Weston *et al*., 2002). The composition of the muscle protein is summarised in Table 2 (Barbut, 2001; Lawrie, 1998).

Table 2 Types of muscle proteins.

Group	Protein	Percentage (%)
Sarcoplasmic		5.5
	Myoglobin	0.2
	Haemoglobin	0.6
	Cytochromes	0.2
	GPD	1.2
	Aldose	0.6
	Creatine kinase	0.5
	Other glycolytic enzymes	2.2
Myofibrillar		11.5
	Myosin	5.5
	Actin	2.5
	Tropomyosin	0.6
	Troponin	0.6
	C-protein	0.3
	α-Actinin	0.3
	β-Actinin	0.3
Stromal		2.0
	Collagen	1.0
	Elastin	0.05
	Mitochondrial	0.95

GPD – Glyceraldehyde phosphate dehydrogenase

4. PROTEIN STRUCTURE

Proteins are polymers which are made of smaller units called amino acids. The general formula of amino acids as adapted from the Nuffield Foundation (1971) is shown in Figure 2.

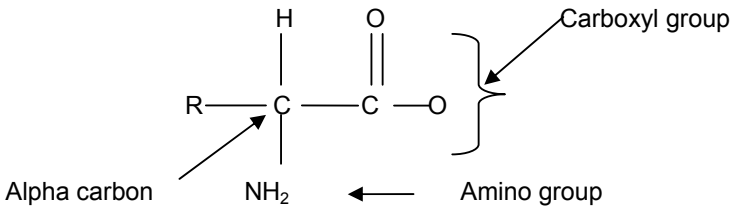


Figure 2 General structure of amino acids.

The characteristic that distinguishes one amino acid from another is its unique side chain (R group, which may be hydrophobic or hydrophilic), and it is the side chain that dictates the chemical properties of an amino acid. The R groups of the amino acids are also the major determinants of both the shape and properties of a protein molecule (Nuffield Foundation, 1971; The structure of proteins, 2002). There are three general categories of side chains: non-polar, polar but uncharged and charged polar (Dickerson & Geise, 1969). Amino acids are covalently bonded together in chains by peptide bonds. If the chain length is short (< 30 amino acids) it is called a peptide. Longer chains are called polypeptides or proteins. Peptide bonds are formed between the carboxyl group of one amino acid and the amino group of the next amino acid. The formation of the peptide bond occurs in a condensation reaction involving the loss of a molecule of water.

The structural features of proteins are usually described at four levels of complexity. These are primary, secondary, tertiary and quaternary structures. The primary structure is the linear arrangement of amino acids in a protein, which are linked through the covalent peptide bonds. The secondary structure involves the folding or coiling of the primary protein structure to form α-helix and β-pleated sheets. These foldings occur due to interactions of the R groups of amino acids residues through hydrogen bonding. The hydrogen bonds are thus responsible for stabilising the helical structures and the pleated sheets of the secondary proteins (The structure of proteins, 2002).The tertiary level of protein structure is the final three-dimensional structure of a protein, which results from a large number of non-covalent interactions between amino acids. These occur when the helical thread is twisted with other threads to form a rope of fibrous proteins or is folded and crumbled into itself in a whole variety of shapes called globular protein shapes (Nuffield Foundation, 1971). The quaternary structure involves the non-covalent interactions that bind multiple polypeptides into a single larger protein. For instance, haemoglobin has a quaternary structure due to the association of two α-globin and two β-globin polyproteins (The structure of proteins, 2002).

The secondary and tertiary structures of protein are principally maintained by hydrogen bonds and to some extent by ionic bonding between NH_3^+ and CO_2^- . Hydrogen bonds are relatively weak and may be broken by heating, and the charges on the NH_3^+ and CO_2^- groups depend on the pH of the medium. Heating (usually above 70°C) and the addition of strong acids and alkalis can bring about the rupture of the links responsible for secondary and tertiary structures, causing the structure to disintegrate. This structural disintegration leads to a loss of the original chemical and physical properties, and the protein is said to have been denatured (Nuffield Foundation, 1971). Actin, myosin and collagen in meat are typical fibrous proteins.

These proteins are built up from three main structures, namely the α-helix, the antiparallel β-pleated sheet and the triple helix. The triple helix is only found in collagen while the α-helix is found in myosin. To stabilise these structures, hydrogen bonding is important (Dickerson & Geise, 1969). The levels of protein structural organisation and the stabilising functional groups are shown in Figure 3 and Figure 4, respectively.

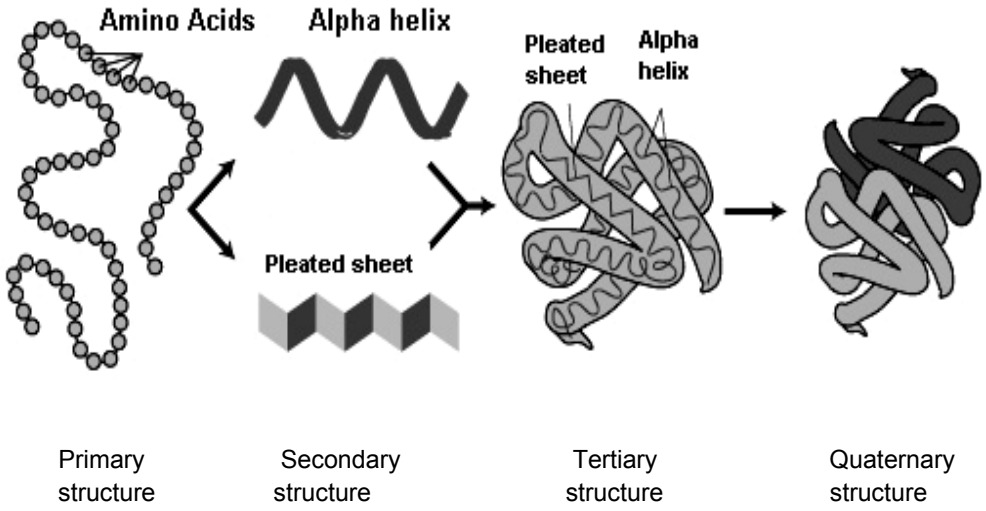


Figure 3 The different types of structure of proteins in solution. Available from http://www.proteomesoftware.com. Accessed on 18 October 2009.

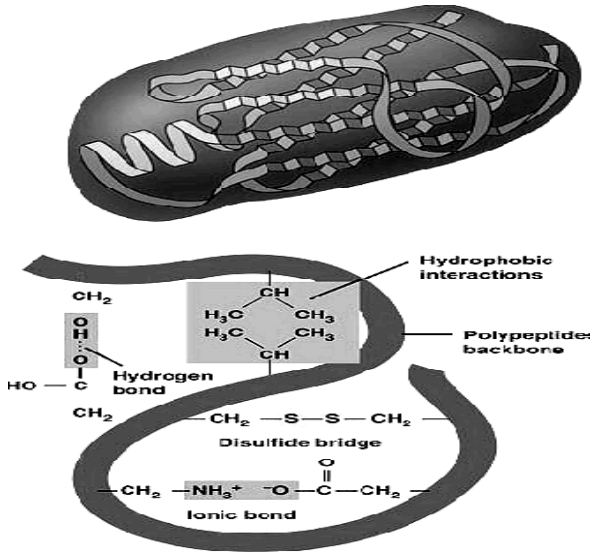


Figure 4 Schematic presentation of the stabilising interactions (hydrophobic interactions, hydrogen bond, polypeptide backbone, disulfide bridge and ionic bond) in proteins. Available from http://www.kvhs.nbed.nb.ca. Accessed on 18 October 2009.

4.1. Gelation of proteins and starch

Protein gelation is an aggregation of denatured molecules with a certain degree of order, resulting in the formation of a continuous network (Wong, 1989). Gelation has been described as a two-stage process (Pomeranz, 1991). The first stage is a denaturation of the native protein into unfolded polypeptides, and the second stage is a gradual association to form the gel matrix. The type of association and, therefore, the nature of the gel, depend on a variety of covalent and non-covalent interactions involving disulfide bonds, hydrogen bonds, ionic and hydrophobic interactions, or a combination of these. Gel formation is an important property of proteins. A gel is a protein network that immobilises a large amount of water. The network is formed by protein-protein interactions. Theoretically, all three muscle proteins – the sarcoplasmic, stromal and myofibrillar fractions – are capable of forming a gel. Practically, however, the first two protein fractions play only a small role in the overall gelation phenomenon in muscle foods (MacFarlane *et al.,* 1977). The myofibrillar proteins, on the other hand, are a superior gelling material and play a vital role in producing desirable textural characteristics in processed muscle foods. In particular, myosin (in pre-rigor state) or actomyosin (in post-rigor state) account for most of the gel-forming capacity of the myofibril protein system (Ashghar *et al*., 1985). Proteins can form gels by acid coagulation, the action of enzymes, heat, and storage. Gels are characterised by having relatively high non-Newtonian viscosity, elasticity, and plasticity.

Protein gels can be simple, filled, mixed or complex. The simplest type of protein gel is one which is formed from a single polypeptide. Heating causes the molecule to unfold and a matrix is created through intermolecular interactions. In a filled gel, one macromolecule forms the gel matrix while the molecules act as fillers within interstitial spaces. The filler molecules can affect certain textural properties and water binding. A filled gel would form when starch or a non gelling protein is added to the meat batters (Foegeding & Lanier, 1987). Starch is widely used as a filler in commercial protein products to strengthen the mechanical properties of the gel, as well as to reduce cost (Verres-Bagnis *et al*., 1993). The role of starch granules is to withdraw water from the system, as they swell and absorb water during gelatinisation. The net result is that the effective concentration of the protein solution increases and when it gels at a higher temperature a strong protein matrix is formed around the gelatinised starch (Aguilera & Baffico, 1997).

A complex gel has a matrix produced by interactions among more than one component. For example, fibrinogen interacts with myosin during gelation. Mixed gels are those in which the gelling macromolecules independently form two or more three-dimensional networks without interactions among the polymers (Foegeding, 1988).

4.2.Factors for gel formation

There are a number of factors which could cause protein gelation. They are classified as physical (heat and pressure) and chemical (acid, ionic and enzymatic). Ionic strength in protein solutions, for instance by adding calcium or sodium chloride, can shield electrostatic charges on the surface of molecules or aggregates. As a result, the electrostatic repulsive forces between the molecules are reduced or neutralised and gelation can occur (Yada, 2004). For example, sarcoplasmic proteins in a salt concentration of 2 to 3% readily coagulate when the meat is cooked at 40 – 60°C (MacFarlane *et al*., 1977). Partially hydrolysed collagen (gelatine) is the best known gelling protein and its gelation is relatively insensitive to ionic strength. Gelatine forms a reversible, cold-set gel, which is stabilised by hydrogen bonds. Unlike collagen, the gel strength of myofibrillar protein increases with protein concentration and heating up to 65 to 70°C at a pH of 6.

The pH of the meat also affects gel formation. At the isoelectric point (pI), that is the pH at which the net charge is zero on the amino acids or proteins (Damodaran, 2008), protein molecules retain the least amount of water due to lack of charges on proteins. This results in poor gels, or it may even prevent gel formation (Smith, 2001). Under normal meat processing conditions, where the pH value is around 6, myofibrillar proteins will be negatively charged and have the ability to bind water.

5. PORK RIND

Pork rind is produced from pork skin (Egelandsdal *et al*., 2005). To make rind, Abiola and Adegbaju (2001) soaked the pork skin in distilled water overnight, followed by trimming the backfat on the skin before scalding. Scalding of the pork skin was done in hot water at 61°C for 5 min to ensure proper removal of the pig's hair from the follicles.

Accordingly to Abiola and Adegbaju (2001), the chemical composition of pork rind is 40.92% moisture, 1.82% ash, 28.69% fat and 27.01% protein. The major protein of the skin is collagen. Collagen affects meat tenderness and is a source of gelatine. There are ten distinct types of collagen found in animal tissues. Type I occurs in skin, bone and tendons and is of most interest in food applications (McLoughlin & McKenna, 1983). Collagen and other connective tissue proteins play a negligible role in gel formation of sausage batters. They are included in formulations for improving water binding, processing yield, juiciness and, palatability and to reduce the cost of processed meat (Eilert *et al*., 1993; Jobling, 1984; Osburn *et al*., 1997).

Collagen can be turned into a useful functional food ingredient called gelatine by denaturation (Yada, 2004). The changes in collagen during cooking are as follows: at 40°C, connective tissue has maximum toughness; at 60°C collagen shrinks; while at 70°C collagen begins to lose its helical structure and to solubilise. From 75°C to 80°C the collagen melts, eventually losing structure and strength, a process called gelatinisation. A collagen solution does not gel until the temperature decreases to 23°C to 33°C (Whiting, 1989).

6. SOYBEAN PROTEIN

The composition of soybeans may vary somewhat according to variety and conditions. Through plant breeding it has been possible to obtain protein levels between 40 and 45% and lipid levels between 18 and 20% (Zhao *et al*., 2008). Soybean products such as flour, concentrates, isolates and textured soy protein are applied in virtually every type of food, including bakery, dairy, meat, breakfast cereal, beverages and meat analogues. They are used in these food systems to increase the protein content and to provide desired functional properties, such as gelling, emulsifying, water-holding and fat-absorbing properties (Liu, 2000; Renkema, 2001; Bayram & Bozkurt, 2007). Table 3 indicates the amount of protein and carbohydrates in some soybean products.

Table 3 Composition of soy protein products (adapted from Basic of Meat Chemistry, 2001).

Item	PROTEIN (%)	Carbohydrates (%)
Soy flour	50	38
Soy protein concentrate	70	24
Isolated soy protein	90	<3

Soybean proteins can be divided into albumins (10%), extracted by water, and globulins (90%), extracted by dilute salt solutions (Fukushima, 1991). Soybean globulins consist of four fractions, namely, 2S (15%), 7S (34%), 11S (41.9%) and 15S (9.1%), according to their sedimentation rates when dissolved at a pH of 7.6 in 0.5M ionic strength buffer (Koshiyama, 1969). The S stands for Sverberg units, which is related to the sedimentation rate of the molecule under centrifugal sedimentation (Lui *et al*., 2007). The 2S fraction is composed of Bowman-Birk and Kunitz trypsin inhibitors, cytrochrome C and α-conglycinin (Catsimpoolas & Ekenstam, 1969; Wolf, 1970). The 7S fraction is heterogeneous and consists predominantly of β- conglycinin and less of γ-conglycinin, lipoxygenases, α-amylases and hemagglutinins or lectins (Nielsen, 1985). The 11S and 15S fractions are pure proteins: glycinin and polymers of glycinin, respectively.

Glycinin and β-conglycinin are the most important soy proteins. Together with α-conglycinin and γ-conglycinin, they form the storage proteins. The 11S globulin presents superior gel-forming ability, while 7S globulin shows better solubility in aqueous systems (Zi *et al*., 2009). Since the 11S globulin (glycinin) forms superior gels, it is very important in the manufacture of polony as well as other sausage products. Gel formation of globular soy proteins such as glycinin is a complex process which often involves several reactions, such as denaturation, dissociation-association and aggregation (Hermansson, 1986). Globular soy proteins have a tertiary structure. Both the tertiary and secondary structures are principally maintained by hydrogen bonds and, to some extent, by ionic bonding. The hydrogen bonds are weak and may be broken by heating. Heating, usually above 70˚C, and the addition of strong acids and alkalis can bring about rupture of the links responsible for the secondary and tertiary structure, thereby leading to the disintegration of the protein conformation. This structural disintegration leads to a loss of the original chemical and physical properties and the protein is said to have been denatured (Nuffield Foundation, 1971).

Denaturation unfolds the protein and functional groups so that the sulfhydryl or hydrophobic groups are exposed. Subsequently, these functional groups can interact with each other to form aggregates (Damodaran & Wang, 1991). The interactions of protein-protein, hydrogen bonding, ionic, hydrophobic and covalent disulphide bonding are important for gel formation (Schmidt, 1981). When the protein concentration is high enough, aggregation leads to the formation of a gel. The aggregation of protein is stronger when the pH is in the isoelectric range (Chodankar *et al*., 2010). A gel is a three-dimensional network holding a large quantity of solvent (the aqueous phase) and showing mechanical rigidity. It is the basic structure in many food products, such as cheese, sausage, tofu, cake and bread (Hongsprabhas, 2001). Gels can either be thermoreversible or thermoset. Thermoreversible means melting on heating and gelling upon cooling, while thermoset means that, once formed by heating, the gel will not melt. Examples of reversible gels are soy and gelatine (Schmidt, 1981). Heat denaturation and gel formation of soy proteins have been studied extensively (Hermansson, 1986). Glycinin gels form between 70 and 95˚C, pH > 6, while β-conglycinin gels form between 55 and 70˚C at a pH lower than 6 (Renkema, 2001).

7. TAPIOCA STARCH

Tapioca starch is obtained from the roots of the cassava plant, which is found in equatorial regions between the Tropic of Cancer and the Tropic of Capricorn. Names for the cassava plant vary depending on the region: yucca (Central America), mandioca or manioca (Brazil), tapioca (India and Malaysia) and cassada or cassava (Africa and Southeast Asia). In North America and Europe, the name cassava is generally applied

to the roots of the plant, whereas tapioca is the name given to the starch and other processed products. The plant belongs to the spurge family (Euphoriaceae). Previously, cassava was described as two edible species of the genus *Manihot ultissima Phol* and *Manihot palmata*, based on the presence of low and high cyanide contents in the roots (or called 'sweet' and 'bitter' cassava), respectively. Recently, both bitter and sweet cassava classes were classified as being the same species of *Manihot esculenta* (Breuninger *et al*., 2009).

The starch is extracted from the roots by wet-milling. The granules of tapioca starch range from 5 to 15 microns in diameter compared to 5 to 20 microns for corn starch and 15 to 75 microns for potato starch. In general, the larger the granules of starch, the easier and faster they swell when hydrated (Kuntz, 2006). The gelatinisation temperature of tapioca starch is in the range of 62 to 73°C (Tarté, 2008). Starch gelatinisation encompasses disruption of the granular structure, and swelling, hydration and solubilisation of the starch molecules (Appleqvist & Debet, 1997). Tapioca starch is composed of 17% amylose and 83% amylopectin. Due to a small amount of amylose, tapioca starch gives a soft gel when pasted. Tapioca starch is used as a thickener in food industries due to its high viscosity, clear appearance and low production costs compared to other starches (Ikeda & Nishinari, 2005).

Natural or native starch does not often have the functional properties required for food processing, such as thickening and stabilisation. Therefore, starches are modified to help prevent undesirable changes in product texture and appearance, such as those caused by the retrogradation or breakdown of starch during processing and storage (Prepared Foods Network, 2008).

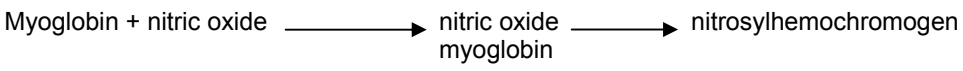
8. EFFECTS OF PROTEIN DENATURATION AND THEIR MEASUREMENT

The function of proteins in meat is for nutrition, texture, colour and water-holding capacity (Processing procedures, 2005). According to Decker (2009), all these functions depend on the physical conformation of proteins. If the native conformation is changed, the protein gets denatured, resulting in the loss of its functional properties. Factors of extreme pH, temperature, shear force and salts (or solvents) disrupt the functional properties of protein. In the manufacture of polony and other cooked sausages, the application of cure and heat are of great significance. Heating (or cooking) causes the denaturation and coagulation of proteins in the sausage (Poli, 2009). In this section, the general effects of protein denaturation on the colour, texture and water-holding capacity of sausage products are discussed.

8.1 Colour and its measurement

Meat colour is dependent on myoglobin protein, which is part of the sarcoplasmic proteins (water soluble proteins). Within the myoglobin protein structure there is a heme structure that normally contains iron (Fe). The oxidation state of this Fe, the protein structure (whether soluble or insoluble) and the total amount of myoglobin in the meat determine its colour (Processing procedures, 2005). Pure myoglobin gets denatured around 85°C, but in meat the haemoproteins begin to coagulate at 65°C, co-precipitating with other muscle proteins (Varnam & Sutherland, 1995).

During meat processing, curing ingredients such as sodium nitrite are added to develop an attractive, stable colour. The basic reaction occurring during colour development is represented as follows:



Nitric oxide myoglobin has an attractive, bright red colour, and is the pigment present in the interior of cured products before heat processing. The colour hue is changed and stabilised upon heat denaturation of the protein portion of the myoglobin. The resulting pigment is nitrosylhemochromogen, which is responsible for the bright pink colour characteristic of cured meats (Aberle *et al*., 2001). The colour of polony and other meat products can be measured using the CIELab colorimeter. In this method, colour is most easily conceived and best defined as a three-dimensional space or solid in which all colours are uniquely located. This colour space is psychometric in nature; that is, the coordinate intervals are highly related to perceived differences. The term L* is the psychometric lightness of the colour. Where the psychometric chroma coordinates a* (green to red axis) and b* (blue to yellow axis), intersect (a* = 0, b* = 0), colours will vary from white to black along the L* axis. Hues are arranged around the perimeter. As the hue angle increases, the colours of the visible spectrum [red (R), yellow (Y), green (G), blue (B), purple (P) and all intermediate hues] are encountered. Chroma is the colour intensity or saturation compared to a neutral gray of the same L*. When a* and b* are near zero, the chroma is near zero. The further away one moves from the L* axis, the more saturated or vivid is the colour (Jones, 1995).

The colour coordinates L*, a*, and b* are often used to define a colour, and colour changes are often presented as changes in a* and b*.The use of hue angle (h_{ab}) and chroma/saturation (C_{ab}) is recommended, since these parameters are easier to comprehend. On the other hand, at low a* and b* values, estimates of h_{ab} are less accurate (Jones, 1995). Both h_{ab} and C_{ab} values arise from simple mathematical manipulations of a* and b*, as given below:

$h_{ab} = \arctan (b^*/a^*)$ $\qquad$ $C_{ab} = (a^* + b^*)^{0.5}$

8.2 Texture and its measurement

Texture is the sensory and functional manifestation of the structural, mechanical and surface properties of foods detected through the senses of vision, hearing, touch and kinaesthetics. This definition reveals that texture is a sensory property, thus, only a human being can perceive and describe it. It also points out that certain physical parameters can be tested and quantified by instrumental methods. The definition also brings out the fact that texture is derived from food structure (molecular, microscopic or macroscopic) (Szezesniak, 2002). For instance during the cooking of whole meat or comminuted meat products, the protein molecules are denatured and the effect manifests itself in the texture. In this section, only the effect of denaturation on texture and how this texture is measured are considered. During thermal processing, the proteins of comminuted meat products are denatured, after which they coagulate. The coagulated proteins interact and cross link with each other, resulting in the formation of a gel-like structure in which the structural units of myofibril proteins and fat particles of the meat batter are bound. The binding of the latter batter components contribute to the development of the final product texture (Acton & Dick, 1989; Barbut, 1995; Xiong, 1997; Mourtzinos *et al*., 2005). The texture of manufactured meat products can be measured by sensory and instrumental methods. Nowadays, the most commonly used instrumental method is probably the compression method of Texture Profile Analysis (TPA), which mimics the conditions to which the material is subjected throughout the mastication process (Bourne, 1978; Scott-Blair, 1958). The TPA parameters which are normally used to evaluate the texture of meat emulsions are hardness (hardness 1 and hardness 2),

cohesiveness, springiness, gumminess and chewiness. Figure 5, adapted from Aalhus *et al*. (2003), shows the TPA force-by-time curve. The definitions of the TPA parameters by Bourne (1968), and as reported by Mittal *et al*. (1992), are as follows:

a) Hardness 1 is the force required for the first compression,
b) Hardness 2 is the peak force for the second compression,
c) Springiness is the distance the sample recovers in height after the first compression (calculated as Length 2 ÷ Length 1),
d) Cohesiveness is the ratio of two total areas under curves (A2/A1),
e) Chewiness is the product of hardness 1, springiness and cohesiveness,
f) Gumminess is the product of hardness 1 and cohesiveness.

The other method which is used to determine meat texture is the Warner-Bratzler shear test method (Lanari *et al.*, 1987; Zhang & Mittal, 1993). However, the literature suggests that this method is used mainly to assess the texture of whole meat, and mostly measures the toughness of meat (Tornberg, 2005).

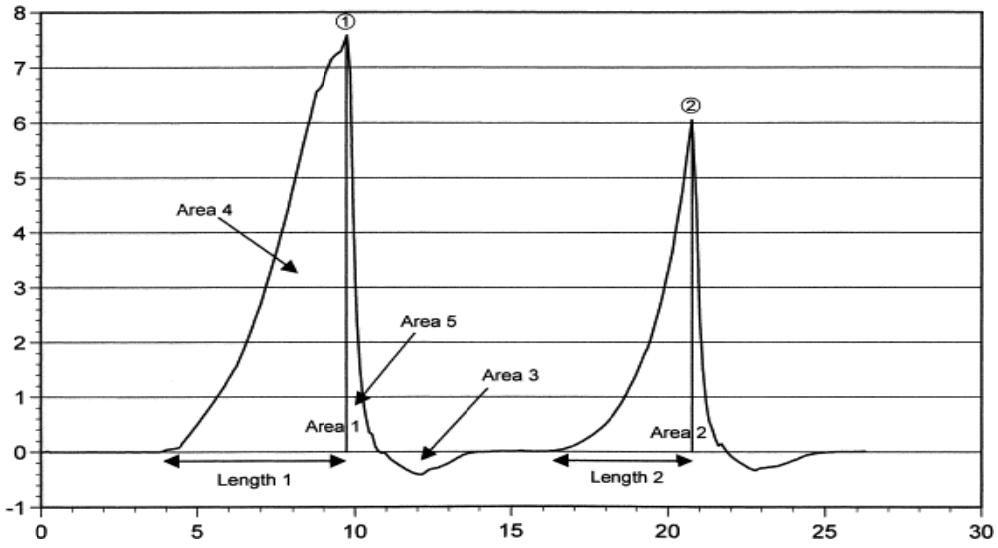


Figure 5 Typical force-by-time plot through two cycles to determine texture profile analysis parameters (adapted from Aalhus *et al*., 2003).

8.3 Water-holding capacity

Water-holding capacity (WHC) is one of the most important properties in both meat and processed products. It affects the yield and juiciness of the final product, whether you are dealing with fresh whole muscle products or comminuted processed products. WHC is defined as the ability of meat to retain its water during the application of external forces such as heating, cutting, mincing or pressing. Many of the physical properties of meat, including the colour, texture and firmness of raw meat are a result of the water-holding

capacity of the meat. Cooked juiciness and tenderness are also partially dependent on WHC (Basics of Meat Chemistry, 2001, Aberle *et al*., 2001).

The proteins in meat are responsible for water-holding capacity (Processing procedures, 2005). Part of this water is bonded electrostatically to the surface of proteins while some of the water is entrapped. The denaturation of the protein affects the structure and charge of the protein and therefore the binding of water and solubility of the protein (Van Laack *et al*., 1994, Bouton & Harris, 1972). Whiting (1988) demonstrated that as the temperature of meat and meat products increased during processing, hydrogen bonds weakened, protein-water interactions decreased, and hydrophobic protein-protein interactions increased. The decrease in protein-water interaction is therefore responsible for increase in protein insolubility and separation of water from heated meat.

The water-holding capacity of meat products is often measured as expressible moisture, cooking loss or purge using a variety of methods. Cooking loss measures the ability of the meat system to bind water and fat after protein denaturation and aggregation whereas expressible moisture refers to the amount of liquid that can be squeezed out of a raw protein system by the application of force (Jauregui *et al.,* 1981). Grau and Hamm (1953) called this method the Filter Paper Press Method. It involves pressing a 0.2 g piece of meat on filter paper between two clear plastic plates to form a thin film. The squeezed water is absorbed by the filter paper to form a ring of expressed juice. The area of meat relative to the ring of expressed juice is an index of WHC. Meat with a high WHC forms a larger area on pressing than meat with a low WHC. This method is also applicable to ground and processed meat (Warris, 2000).

9. MANUFACTURED MEATS REGULATIONS

Having discussed the general methods used in the production of cooked sausages, it is imperative to consider the regulations which are used as guidelines in the production of sausages, polony inclusive, in Southern Africa, particularly in Zambia and South Africa.

9.1 Zambian Food Laws

Zambia, like many other countries, uses a fragmented food control system. A fragmented system is where regulations and the functions of the different government organisations are duplicated and some of the regulations and functions are neither harmonised nor coordinated (Chanda *et al*., 2009). For instance, the food control services in Zambia are administered by four ministries (FLIP, 2000). These ministries are the:

a. Ministry of Health
b. Ministry of Agriculture
c. Ministry of Trade and Industry
d. Ministry of Local Government and Housing

Each of the aforementioned ministries enforces the Acts through organised committees, boards (for example the Central Board of Health for the Ministry of Health) or a statutory body. According to Lexadine (1996 – 2010), some of the Acts which are in existence in Zambia that contain provisions for food-related issues are:

a. Food and Drugs Act, Cap 303

b. Public Health Act, Cap 295
c. Standards Act, Cap 416
d. Agricultural and Lands Act, Cap 187

The Food and Drugs Act and the Public Health Act both fall under the umbrella of the Health Law of Zambia while the Standards Act belongs to the Administrative or Public Law. The Ministry of Health, enforces the Public Health Act and the Food and Drugs Act through the agencies of the Central Board of Health and the Food and Drugs Board, respectively. The Ministry of Local Government administers the Public Health Act through municipalities. The Ministry of Trade and Industry, through the statutory organisation called Zambia Bureau of Standards (ZABS), to which the Standards Act belongs, is responsible for the preparation and promulgation of Zambian Standards. The Agricultural and Lands Act is under the Ministry of Agriculture. It is enforced through the Plant Quarantine and Livestock Development Services (FLIP, 2000). Due to the difficulty which was experienced in accessing most of the above named Acts, only the meat processing provisions found in the Food and Drugs Act are discussed.

9.1.1 The Food and Drugs Act of Zambia

In the Food and Drugs Act, Statutory Instrument No. 90 of 2001, Cap. 303 of the laws of Zambia, there is no specific regulation on polony. However, the Act refers to the following in regulation 360:

"Sausage or sausage meat shall be the fresh or preserved comminuted meat to which has been added salt, a preservative as set out in part XI of the Twenty-second schedule, and spices as set out in regulations 377 to 386; may be enclosed in a casing, dipped in vinegar, smoked or cooked; and may contain animal fat, filler, beef tripe, liver, fresh blood from meat cattle, sugar dextrose or glucose, other seasoning, harmless Lacto bacilli cultures, lactic acid starter culture, *Pediococcus cerevisiae*, meat binder and blood plasma" (Food and Drugs Act, 2001).

However, the amounts of salt and spices referred to in the Twenty-second schedule and regulations 377 to 386, respectively, are not there in the Food and Drugs Act. This omission leaves room for the manufacturers of sausages to add any quantities of salt and spices. The omission could also make it difficult to prosecute individuals or companies involved in such malpractices.

As for the amount of fat the product should contain, no specific quantity is mentioned in regulation 360 except for regulation 357, which states that minced beef or ground beef shall be comminuted beef meat and shall contain no more than 20 per centum of fat: provided that where the product is represented by any means whatsoever as being lean, it shall contain no more than 10 per centum of fat.

9.2 South African Food Laws

The structure of the government in South Africa is divided into three levels, namely, national, provincial and local. The food control system is conducted under the terms of at least fourteen acts that are administered and enforced by numerous authorities and assignees at all three tiers of the government (Gain Report, 2006). There are three agencies that are responsible for administering the food control system. These are the National Department of Health, the Department of Agriculture and the South African Bureau of Standards

(SABS). All three have separate mandates regarding food safety and food standards (http://www-foodlabelling.co.za/info).

9.2.1. Fragmentation of legislation

The chief act relating directly to food control is the Food, Cosmetics and Disinfectant Act of 1972 (Act 54). It is administered by the Department of Health (DoH). The act addresses the control of safety aspects of foods and specifically makes provision for the sale, manufacture and importation of certain foodstuffs (Chanda *et al*., 2009).

Another principal act, the Agricultural Products Standards (Act 119 of 1990), administered by the Department of Agriculture (DoA), deals largely with quality issues and controls the sale and export of a variety of foodstuffs. The Act also makes provision for partial marketing of foodstuffs in relation to quality issues under the Marketing Act of 1968 (Act 59), and more specifically the Marketing of Agricultural Products Act of 1996 (Act 47) (Chanda *et al*., 2009). The South African Bureau of Standards (SABS) falls under the Ministry of Trade and Industry and is responsible for the safety of certain products (http://www-foodlabelling.co.za/info). In the next three sections, the standards pertaining to ingredients which are used in the manufacture of meat products, polony inclusive, are reviewed.

9.2.2. Food, Drugs and Disinfectant (FDD) Act No. 13 of 1929

The regulations regarding the composition of meat products are framed under section 14 of the FDD Act. Meat is one of the most important ingredients for polony processing. In section 14 (1) (a), it states that meat to be "used in meat products should be clean, sound and wholesome flesh of animals or birds used as food. Meat other than that of bovines, sheep, pigs and goats should bear a label indicating its nature." (Department of Health, 1930).

Since birds are not mentioned in the latter part of this quotation, it means that if the meat of birds such as chicken MRM, is used in the processing of a meat product, that meat product shall bear a label indicating the nature of such an ingredient.

9.2.2.1. Composition of manufactured meat

In sections 14 (3) (a) and 14 (4) (i) it is essential to note that there is a difference between processed meat and manufactured meat. Processed meat is simple or mixed meat which has been subjected to cooking, curing, drying, smoking or any combination of such processes, while manufactured meat is meat which has been minced and/or ground in addition to one or more of the processes enumerated for processed meat. Examples of manufactured meats are polonies, saveloys, meat pastes, brawn, meat loaves or rolls and similar articles containing meat, but excluding food products of the nature of sausage rolls and meat pies (Department of Health, 1930). The FDD Act of 1929 permits manufactured meats, including polony, the product which was manufactured in this project, to contain the following ingredients: "spices and flavouring, with or without milk, eggs, agar-agar, gelatine and wholesome farinaceous or other vegetable substances. They may contain added phosphates, not exceeding 0.5 per cent of the final product, added ascorbic acid, permitted preservatives and colouring matter, saltpetre and potassium or sodium nitrite: provided that the finished article shall not contain more than 200 ppm of nitrite calculated as sodium nitrite. The total meat

content shall not be less than 75 per cent. If packed in any container, brine, fat, agar-agar and/or gelatine may be used as a packing medium." (Department of Health, 1930).

In all cases where it is necessary to calculate total meat under regulation 14 (1), (2), (3) and (4), the formula used shall be:

Percentage lean meat = percentage protein nitrogen x 30

Percentage total meat = percentage lean meat + percentage fat

Farinaceous materials according to Thurber & Co. (http://cgi.ebay.com) are commodities which are highly nutritious and provide energy and dietary fibre; they include starchy flours, cereals, pulses, starchy vegetables and even parts of trees. The only weakness observed in the FDD Act of 1929 is that the maximum permitted levels of some additives for use in manufactured meats have been left out, as indicated in regulation 14 (1) (a). These ingredients include ascorbic acid, milk, eggs, gelatine, spices and flavouring, permitted preservatives and colouring matter. However, Government Notice No. R1008 of the Food, Cosmetics and Disinfectants (FCD) Act of 1972 (Act No. 54) permits the use of up to 30 mg/kg of erythrosine BS colour in processed meats. Similarly, annatto is also allowed in sausages (except boerewors, species sausages and mixed sausages) up to a level of 10 mg/kg (Department of Health, 1996). R1055 of 2002 permits herbs and spices not exceeding 2% (Department of Health, 2002). In Government Notice No. R965 of FCD Act of 1972, under preservatives and antioxidants, manufactured meat products, including sausages (species and mixed) could contain erythorbic acid or sodium erythorbate. The amount of erythorbate or erythorbic acid is not indicated, but its use depends on good manufacturing practices (GMP) (Department of Health, 1977). Erythrosine BS (FD & C Red No.3) is a synthetic colouring material made of disodium or dipotassium salt of 2,4,5,7-tetraiodofluorescein (Butterworth *et al*., 1976). Annato is red-orange natural colorant obtained from the pericarp of *Bixa orellana L* (Zarringhalami, *et al*., 2009).

9.2.4 Foodstuffs, Cosmetics and Disinfectant Act (FCD) of 1972

In 1972, the 1929 Food, Drugs and Disinfectant Act (Act No. 13) was repealed and was now called the Food, Cosmetic and Disinfectant Act (Act No. 54). In section 15 of the 1972 Act, the composition of polony and other manufactured meat products is omitted. However, the section lists the composition of raw boerewors, raw species sausage and raw mixed-species sausage. According to the South African National Standards (SANS 885) of 2003, examples of species sausage and mixed species sausage are pork sausage, beef sausage and beef and mutton sausage. It is stipulated that boerewors is to contain a minimum of 90% total meat and not more 30% fat content. No offal is allowed, except where such offal is to be used solely as the casing of raw boerewors. Boerewors is to contain 0.02 g of Ca/100g of product mass. Additives permitted in boerewors are cereal products or starch, vinegar, spices, herbs, salt, permitted food additives and water. As for raw species and raw mixed-species sausages, a minimum of 75% total meat and not more than 30% fat is allowed.

10. CONCLUSION

The processing of polony including the gelation of meat proteins, soya protein, pork rind and starch, has been reviewed. This chapter also considered some of the regulations which pertain to meat processing in Zambia and South Africa. The next chapter considered how an optimal combination of protein ingredients,

such as chicken MRM, soya protein and pork rind can be established through formulation to produce a cost-effective polony product.

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CHAPTER 3

FORMULATION OF LOW-COST POLONY

ABSTRACT

To establish the combination of ingredients with the lowest cost in the production of a fixed 10% protein polony, the protein content of the raw materials, chicken mechanically recovered meat (MRM), pork rind and soya flour, was analysed for moisture, nitrogen, fat and ash. The pork rind was precooked to soften it and was subsequently emulsified with an equal amount of water. This added water was accounted for in subsequent formulations of nine treatments of polony. The analytical values for nitrogen and fat were used to calculate the percentages of chicken MRM, rind and soya required to obtain 10% protein in all treatments. The percentage mean values of nitrogen used were: 1.9% for chicken MRM, 7.4% for soya and 2.9% for pork rind emulsion. For fat, the percentage mean values used were: 17.4%, 5.6% and 5.7% for MRM, soya and pork rind emulsion respectively. The other food-grade additives were kept constant for all treatments. Water was the only non-protein additive which was varing. The experimental design used in the study was a two-factor x three-level factorial design, with soya levels varying between 0%, 4% and 8% and pork rind varying between 0%, 8% and 16%. The combinations of these levels of two proteins resulted in nine treatments of polony, each using chicken MRM as meat protein source. Each treatment was replicated ten times. Cost calculations on all nine treatments varied from R4.54/kg to R2.91/kg as MRM was replaced by increasing amounts of soya flour and pork rind.

Keywords: Formulation, polony, cost calculation

1. INTRODUCTION

Generally, the success of any food product on the market is dependent upon the quality of its flavour and texture, its stability under various storage conditions, its nutritional value, colour, palatability, yield and safety, and its cost of production. Such factors are intimately related to the ingredients in the food product, as well as to the physical processes and handling procedures to which it has been subjected (Baker *et al*., 1988; Flores *et al*., 2007; Colmenero, 2000). The inclusion of ingredients in the formulation of a particular product has two goals. The first goal is to produce products of uniform appearance, composition, flavour and physical properties from batch to batch each day. The basic requirement for producing uniform processed meat products is proper selection and preparation of meat ingredients (Aberle *et al*., 2001). The second goal is to produce products that meet preset quality standards by using raw materials at affordable prices (Aberle *et al*., 2001). As a result of fluctuations in the cost of various meat ingredients, it often is economically desirable to partially or completely substitute one ingredient for another. The process of formulation determines the extent to which substitutions can be made, and when, in economic terms, to do so. Linear programming procedures for least-cost formulation are widely used in the meat industry, mainly to help accomplish these goals. It is one of the functions of quality control to make sure that the formula used will assist in producing a product that meets defined quality standards (Aberle *et al*., 2001). Both of the goals which have been discussed depend on the availability of accurate information on the composition, colour, and chemical and physical properties of potential raw materials (Aberle *et al*., 2001). On the issue of composition, for example, the only way the composition of the ingredient can be known is by subjecting the raw materials to chemical analyses. From the obtained values of composition, the food processor can determine how to proceed with the formulation of the meat product.

The formulation of low cost meat products, polony inclusive, is extremely important in countries with poorer communities. In such countries the majority of consumers cannot afford to buy meat and meat products regularly, as these products are usually quite expensive (Whitney & Rolfes, 1999). For instance, South Africa is regarded as an upper-middle-income country, although poverty is widely acknowledged as being among the most serious problems currently facing South Africa (Agbola, 2003; Budlender, 1999). According to the surveys of 2005 and 2006 conducted by Statistics South Africa to establish the profile of poverty, and as reported by Armstrong *et al*. (2009), it has been established that 33.2% of the households in South Africa consume below the lower-bound poverty line, while 53% of the households consume less than the upper-bound poverty line. In South Africa, the lower-bound poverty line is at R322, while the upper bound is at R593. The poverty line provides for essential food and non-food consumption which someone can purchase using R322 or R593 per month. As a result of the low poverty levels and the high prices of meat and meat products, some researchers advocate the use of non-meat ingredients, which are also called extenders, binders or fillers, in emulsion-type meat products. The goal of the inclusion of non-meat proteins in emulsified products is to provide for more affordable, high quality protein products (Yetim *et al*., 2001, Aberle *et al*., 2001).

In the current study, different combinations of pork rind and deflavoured soya flour were used to partially replace chicken MRM in the formulation of nine treatments of polony with the objective of finding the cheapest combination of these protein ingredients. To achieve this, proximate analysis was done to determine the chemical composition of the major ingredients. The determined percentage values of protein

were then used for calculating the percentages of ingredients needed for each treatment formulation. Thereafter the percentage quantities of ingredients thus obtained were used in a cost calculation.

2. MATERIALS AND METHODS

2.1. Sourcing, storage and preparation of ingredients

Chicken MRM, pork rind and soya flour were each sourced as a single batch from which all the proportions or quantities used in preparing the nine treatments of polony were taken. Both pork rind and MRM were obtained from Etlin International (Bay Road, Table Bay Harbour, Cape Town, Western Cape, South Africa) in a frozen form, while tapioca starch and soya flour in powder form were supplied by Maccullum and Associates (Unit 410 Pebble Beach, De Beers Avenue, Somerset West, South Africa). The phosphate salt was supplied by Protea Food Division (54 Killarney Avenue, Killarney Gardens, Milnerton, Cape Town, 7441, South Africa). Spices and sodium chloride used were bought from supermarkets in powder form. The erythrosine dye, nitrite and ascorbic acid were all supplied in powder form by Functional Foods Ltd (PO Box 2287, Dennesig 7601, Stellenbosch, South Africa). Prior to their utilisation, the chicken MRM and pork rind were stored at -18°C. The soya flour, tapioca starch, seasonings, salt, phosphate, curing ingredients and colorant were stored at room temperature under dry conditions before and after being weighed in quantities used for further processing.

2.1.1. Preparation of pork rind emulsion and MRM

Initially, the frozen tough pork rind were cut into small pieces for easy accommodation in a pot. After that the rind was softened by precooking, as raw pork rind cannot easily be emulsified in a bowl cutter during polony processing. Since the bowl cutter which was used for chopping had a capacity of 15 kg, 7.5 kg of rind was cooked by boiling in 7.5 kg of water. The cooking time varied from 4 to 5 h for the three batches of pork rind cooked. After cooking, the pork rind and water mixture was reweighed and water added to make up the 15 kg before chopping the mixture in the bowl cutter until a fine, sticky homogenous mass called rind emulsion was formed. The rind emulsion was then allowed to cool to room temperature prior to weighing and vacuum packaging. The rind emulsion was subsequently stored at -18°C until chemically analysed or used in the polony processing.

The only preparation done on the frozen MRM involved cutting it into smaller blocks (of about 4 cm x 4 cm x 4 cm) for the purpose of easy fitting into the bowl cutter. The cut blocks of MRM were vacuum sealed and frozen until the day they were used.

2.2. Proximate analyses

Only the protein-rich materials – the pork rind emulsion, soya flour and chicken MRM – were analysed for nitrogen, fat, moisture and ash prior to their utilisation in polony formulation.

2.2.1. Protein determination

Protein was determined by the Kjeldahl AOAC method No. 976.05 (AOAC, 2002). About 2 g of each sample in its natural state was weighed into the digesting tube to which the catalyst mixture of 5 g anhydrous copper

sulphate and a small amount of selenium had been added. A blank digesting tube with only the catalyst was also prepared. To each sample, the blank inclusive, 20 mL of 95 to 98% concentrated sulphuric acid, was added and digestion was carried out for 1 h in a fume hood until the samples were colourless. The digested samples and the blank were cooled for 30 min, followed by the addition of 50 mL distilled water. The cooled diluted samples and blank were neutralised using 20 mL of 50% sodium hydroxide on the Kjeltec system. Steam was used to distil ammonia from the neutralised sample solution. The distilled ammonia was trapped in 30 mL boric acid indicator solution. The total volume of the distillate and boric acid in a conical flask was 150 mL. The distillate and boric acid mixture, which was blue in colour, was titrated with 0.5 M sulphuric acid until the solution just turned pink. The titration volumes for each sample and for the blank were noted. The titration volumes were used to calculate the percentage nitrogen. The formula which was used for the calculation was as follows:

$$\%N = \frac{A\ (mL) \times M \times 100\%}{1000 \times \text{mass of sample used (g)}}$$

where:

%N is the crude nitrogen in percentage,

A is the volume of standard sulphuric acid used for the sample titration minus the volume of acid used for the blank titration,

M is the molar concentration of the standard sulphuric acid used for the titration.

2.2.2. Fat determination

Fat was determined by the Soxtec method (AOAC method 920.39 of 2002). Initially, the samples of pork rind emulsion and chicken MRM were dried at 60°C overnight. The soya flour was not dried, as it was already dehydrated. From the dried protein sources, soya flour inclusive, three samples (≈ 2 g) of each were weighed into the paper thimbles. The samples in the thimbles were covered with cotton to prevent them from being washed out during extraction. The thimbles were mounted on the soxtec system and extraction procedures were followed as outlined in the AOAC (2002) manual.

The fat was extracted from the samples using 50 mL of diethyl ether contained in pre-weighed aluminium beakers. After extraction, the aluminium beakers with fat were dried overnight at 105°C. Thereafter, the beakers were removed from the oven, cooled in a dessicator for 30 min and weighed. The mass of the beaker plus fat, the sample, and the clean beaker were used to calculate the percentage of fat, using the following formula:

$$\%\text{Ether extract (\%fat)} = \frac{\text{mass of beaker and fat (g)} - \text{mass of beaker (g)}}{\text{mass of sample (g)}} \times 100\%$$

The values of ether extract that were determined were for the dry samples. To obtain the %fat in the wet samples, the following formula was used:

$$\%\text{fat in wet samples} = \frac{\%\text{fat in dry samples} \times \text{dry matter}}{100}$$

where dry matter = 100% - moisture (%).

2.2.3. Moisture and ash determination

Moisture was determined using AOAC method No. 934.01 (AOAC, 2002). Approximately 2 g of wet raw sample material was weighed into pre-weighed crucibles (in triplicate) and dried overnight at 105°C. Each triplicate was repeated thrice. The crucibles with dry samples were then removed from the oven, cooled in a dessicator for 30 min and weighed. The percentage moisture was calculated as follows:

$$\% \text{ moisture} = \frac{\text{mass of wet sample (g)} - [\text{mass of crucible and dry sample (g)} - \text{mass of crucible (g)}]}{\text{mass of wet sample (g)}} \times 100\%$$

The ash content was determined by first drying the samples at 105°C to reduce moisture. The reduction of moisture prior to ashing prevents the explosion of the sample in the furnace. Ashing was done in a muffle furnace at 500°C for 6 h in accordance with AOAC method 942.05 (AOAC, 2002). Thereafter, the furnace was switched off and the samples were allowed to cool in the furnace for 45 min before being cooled further in a dessicator for 30 min. The cooled crucibles with ash were weighed and the ash content was calculated as follows:

$$\%\text{ash} = \frac{\text{mass of crucible and ash (g)} - \text{mass of crucible (g)}}{\text{mass of wet sample (g)}} \times 100\%$$

The values of nitrogen and fat were used in the formulation of the low-cost polony. In Section 2.5, the formulation of the nine treatments of polony will be discussed.

2.3. Physical analyses

The only physical measurement made during the polony formulation was pH. The pH was measured in triplicate in the raw batter of each of the nine treatments using a Crison 25 pH-meter.

2.4. Polony formulation

The average analytical values for nitrogen (%) and fat (%) for the MRM, rind emulsion and soya flour were used to formulate the nine treatments to contain 10% protein. The average values of nitrogen were 1.9%, 2.9%, and 7.4% for the chicken MRM, rind emulsion and soya flour, respectively. The average values for fat were 17.3%, 5.7% and 5.6% for the MRM, pork rind emulsion and soya flour, respectively.

All nine treatments were formulated to contain 10% protein, based on a conversion factor of 6.25 for %N to %protein, and the predetermined amounts of soya flour (0%, 4% and 8%) and predetermined amount of pork rind (0%, 8% and 16%). The theoretical percentage of lean meat equivalent (%LME) and the percentage of fat by ether extract (%EE) were also calculated using a conversion factor of 4.8 for %protein to %LME (SANS 885, 2003).

2.5. Cost calculation

In order to determine the most affordable polony treatment, the various formulation ingredients obtained were used in the cost calculation. The percentage values of ingredients were converted into mass of ingredients

per kg of polony. The mass of the ingredient per kg of polony was multiplied by the unit cost of the ingredient to obtain the total cost for each ingredient.

2.6. Polony processing

For each treatment, a 15 kg emulsion (from which ten polony samples were made) was prepared. For all the treatments, the order of adding the ingredients was the same. All ingredients were added when the bowl cutter was running at low speed. After that, the speed was increased for the final chopping. The capacity of the bowl cutter was 15 kg. The MRM was added and chopped first, followed by adding the salt, nitrite, the phosphate and one third of the water. This was followed by adding the rind emulsion. After that, soya flour was added into the bowl cutter and chopped for 2 min before adding spices and another third of the water. The tapioca starch was then added, after which the ascorbic acid and the last third of the water was added. Water at room temperature was used for the five treatments because both the chicken MRM and rind emulsion were still frozen, while ice was used for the last four treatments after the MRM and rind emulsion had thawed.

The end temperatures after chopping the polony emulsion varied between 12°C and 17°C. At the end of chopping each treatment, three samples of raw batter were taken and their pH was measured with a Crison 25 portable pH-meter. Each emulsified treatment was tightly stuffed into 90 mm waterproof polyethylene casings and tied off. The polonies were cooked in a steam bath for ≈ 2 h to an internal temperature of 80°C as measured by a thermocouple. The cooked polony was then cooled in clean running water prior to storage at 4°C until chemical, instrumental and sensory analyses were done.

2.7. Statistical analysis

The univariate analysis of variance (ANOVA) was performed on the proximate results of the raw materials using the General Linear Model (GLM) procedures of SAS statistical software version 9.1 (SAS Institute Inc., Cary, NC, USA). The Shapiro-Wilk test was used to test for normality of the data (Shapiro, 1965).

3. RESULTS AND DISCUSSION

3.1. Proximate analyses

The proximate analysis results are reported in Table 1. Hamm and Searcy (1981) noted proximate mean values for MRM as 66.6 – 70.0% for moisture, 11.9 – 16.7% for protein, 13.8 – 22.0% for fat and 0.9 – 1.5% for ash. The values of Hamm and Searcy (1981) are similar to those found in this investigation.

Pork rind contains 27.1% protein, 28.7% fat, 40.9% moisture and 1.82% ash (Abiola & Adegbaju, 2001). In the present investigation, the pork rind emulsion was prepared with 50% pork rind and 50% water. Transforming the analytical values in Table 1 to pure rind, values of 37.2% protein, 40.8% moisture, 11.4% fat and 0.6% ash were calculated. The fat content of the pork rind used in this study was half of what Abiola and Adegbaju (2001) noted, thus accounting for the higher protein values of the current study.

The mean value of protein in soya flour was found to be 46.4%. In Basic Chemistry of Meat (2001), soya flour is noted to have a protein content of 50%. However, the value of 46.6% is still acceptable, as the different sources of soybeans used for making soya flour vary in protein content.

Table 1 Proximate analysis mean values (±SE) for wet raw materials.

Ingredient	Moisture (%)	Fat (%)	Protein (%)	Ash (%)
Chicken MRM	67.0 ± 0.26	17.4 ± 0.27	12.0 ± 0.18	0.9 ± 0.04
Pork rind emulsion	70.4 ± 0.33	5.7 ± 0.34	18.6 ± 0.14	0.3 ± 0.05
Soya flour	6.1 ± 0.07	5.6 ± 0.11	46.4 ± 0.30	7.7 ± 0.21

MRM – mechanically recovered meat

SE – standard error

3.2. Physical analyses (pH)

The ANOVA results for the raw batter (Table 2) indicate that pork rind and soya protein interacted significantly (P = 0.0001). As shown in Figure 1, all the pH mean values in which no soya was added (S0) to the raw batter differed significantly ($P \leq 0.05$) at all levels of pork rind, and the mean values of S0 were higher than those in which soya was added at 4% (S4) and 8% (S8). It was also observed that the S0 pH values were increasing as rind increased, while the S4 and S8 pH values were constant at all levels of rind, except for S4, which increased at 16% pork rind level. The S0 results show that the use of pork rind in the absence of soya tends to increase the pH of raw batter. These findings are consistent with what Fitjik and Mandigo (1998) reported when they added pork skin at a rate of 10 and 20% to fresh pork sausage. The added pork skin, which had a pH of 7.06, increased the fresh sausage pH. In treatments in which some soya was added, as shown by S4, the mean values of the pH obtained at all rind levels were lower than those for S0. The pH mean values for treatments with 8% soya were the lowest, as can be seen from line S8. This means that the combination of soya and pork rind tends to bring down the raw sausage batter pH, and the reduction is more as soya protein increases.

Table 2 ANOVA showing the level of significance for the main effects and interaction effects of pork rind and soya proteins on raw batter pH.

Source	DF	Type I SS	Mean square	F value	Pr > F
Batch	1	0.00125000	0.00125000	8.0	0.0222
Rind	2	0.03685278	0.01842639	117.93	<0.0001
Soya	2	0.21863611	0.10931806	699.64	<0.0001
Rind x soya	4	0.01650556	0.00412639	26.41	0.0001

DF – degree(s) of freedom

Rind – pork rind main effect

Soya – soya flour main effect

Rind x soya – pork rind and soya flour interaction effect

SS – sum of squares

F value – variance ratio

Pr > F – significance probability (P-value)

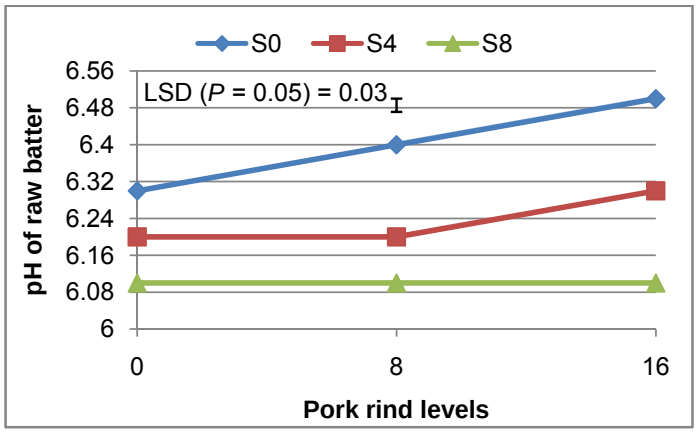

Figure 1 Mean values of raw batter pH of nine treatments with three levels of rind (levels 0, 8 & 16%) and soya (levels 0, 4 and 8%, shown as S0, S4 & S8).

3.3. Polony formulation

Table 3 shows the percentages of ingredients used to theoretically obtain 10% protein (48% LME) for each formulation or treatment. The table also shows the theoretical values for the percentage of fat (%EE). The values of the additives were fixed. The aim of this study was to keep the theoretical protein content constant at 10% protein by using varying amounts of soya flour and pork rind and by reducing the amount of MRM utilised. Treatment 1 (R0S0), to which no soya protein and pork rind were added, was used as the control. The additives which were used in the formulation were 8% tapioca starch, 1.8% salt, 0.016% nitrite, 0.3% phosphate, 0.05% ascorbic acid, 0.02% erythrosine dye, 0.1% each for black pepper and cayenne pepper, 0.03% ginger, 0.2% garlic, and 0.05% each for nutmeg and coriander. Only the variable amounts of MRM, soya flour, pork rind and water were used in the cost calculations, which excluded the costs of the fixed ingredients in order to compare the direct effect of the varying ingredients.

In line with the purpose of this research, the theoretical values of %TME (%LME + %EE) obtained for each formulated treatment were less than 75%. The %EE values obtained in this study were all dependent on the fat content of the raw materials since no fat was added to each treatment formulation. The values of %EE were also less than 30%, contrary to what SANS 885 of 2003 recommends. The formulation of low fat product such as these in the current study is a good development because it meets the current demand by consumers for low fat products. However, the low fat manufactured meat products are associated with negative aspects such as dryness, poor texture and flavour. Poor texture and flavour is as a result of less interaction between fat and protein. This means that the polony treatments obtained in this study were expected to have poor texture and flavour as the fat content reduced across treatments and as the replacement of high fat MRM increased.

Table 3 Percentage ingredients for the formulation of each treatment with theoretical values for %LME and %EE

Ingredient	R0S0	%LME	%EE	R0S4	%LME	%EE	R0S8	%LME	%EE
MRM	82.6	48	15.1	67.4	39.2	12.3	52.2	30.3	9.6
Pork rind	0	0	0	0	0	0	0	0	0
Soy1909	0	0	0	4	8.8	0.24	8	17.7	0.5
Water	6.6			17.9			29.1		
Additives	10.7			10.7			10.7		
Totals	100	48	15.1	100	48	12.6	100	48	10.1

Ingredient	R8S0	%LME	%EE	R8S4	%LME	%EE	R8S8	%LME	%EE
MRM	58.6	34	10.7	43.4	25.2	7.9	28.2	16.4	5.2
Pork rind	8	14	0.7	8	14	0.7	8	13.9	0.7
Soy1909	0	0	0	4	8.8	0.2	8	17.7	0.5
Water	22.6			33.9			45.1		
Additives	10.7			10.7			10.7		
Totals	100	48	11.4	100	48	8.8	100	48	6.4

Ingredient	R16S0	%LME	%EE	R16S4	%LME	%EE	R16S8	%LME	%EE
MRM	34.5	20.1	6.3	19.3	11.2	3.5	4.1	2.4	0.7
Pork rind	16	27.9	1.4	16	28	1.4	16	27.9	1.4
Soy1909	0	0	0	4	8.8	0.2	8	17.7	0.5
Water	38.8			50			61.2		
Additives	10.7			10.7			10.7		
Totals	100	48	7.7	100	48	5.1	100	48	2.6

Treatment combinations from treatment 1 to treatment 9: R0S0 – 0% pork rind & 0% soya flour; R0S4 – 0% pork rind & 4% soya flour; R0S8 – 0% pork rind & 8% soya four; R8S0 – 8% pork rind & 0% soya flour; R8S4 – 8% pork rind & 4% soya flour; R8S8 – 8% pork rind & 8% soya flour; R16S0 – 16% pork rind & 0% soya flour; R16S8 – 16% pork rind & 8% soya flour; R16S8 – 16% pork rind & 8% soya flour

%EE – %ether extract or expected %fat content of each treatment

%LME – %lean meat equivalent expected for each treatment

3.4. Cost calculation

The results in Table 4 shows that the treatment in which the highest percentage of chicken MRM (≈ 83%) was used (R0S0) was the most costly to make (R4.54) while the one in which the lowest percentage of MRM (≈ 4%) was used in combination with 16% rind and 8% soya (R16S8) yielded the cheapest polony (R2.91). These results shows that the production of polony by varying the percentages of ingredients is possible and this could afford the manufacturer an opportunity to choose combinations that gives optimal production as well as those which meet consumer satisfaction. Consumer satisfaction can only be achieved if polony is affordable and if its attributes are acceptable. In the next chapter, various polony attributes for each treatment were determined and possible factors affecting these attributes were discussed.

Table 4 The effect of the combinations of three protein sources and water on the cost of each treatment (South African Rand as determined in October 2010).

Treatments	Ingredient	% ingredient	Ingredient mass (kg/kg polony)	Unit cost (Rand/kg)	Total Cost/kg (Rand)
	MRM	82.6	0.826	5.50	4.54
R0S0	Pork rind	0	0	8.50	0.00
	Soya flour	0	0	16.50	0.00
	Water*	6.6	0.066	0.01	0.00
Grand total					**4.54**
	MRM	67.4	0.674	5.50	3.71
R0S4	Pork rind	0	0	8.50	0.00
	Soya flour	4	0.04	16.50	0.66
	Water	17.9	0.179	0.01	0.00
Grand total					**4.37**
	MRM	52.2	0.522	5.50	2.87
R0S8	Pork rind	0	0	8.50	0.00
	Soya flour	8	0.08	16.50	1.32
	Water	29.1	0.437	0.01	0.00
Grand total					**4.19**
	MRM	58.6	0.586	5.50	3.22
R8S0	Pork rind	8	0.08	8.50	0.68
	Soya flour	0	0	16.50	0.00
	Water	22.7	0.227	0.01	0.00
Grand total					**3.90**
	MRM	43.4	0.434	5.50	2.39
R8S4	Pork rind	8	0.08	8.50	0.68
	Soya flour	4	0.04	16.50	0.66
	Water	33.9	0.509	0.01	0.01
Grand total					**3.74**
	MRM	28.2	0.282	5.50	1.55
R8S8	Pork rind	8	0.08	8.50	0.68
	Soya flour	8	0.08	16.50	1.32
	Water	45.1	0.451	0.01	0.00
Grand total					**3.55**
	MRM	34.5	0.345	5.50	1.87
R16S0	Pork rind	16	0.16	8.50	1.36
	Soya flour	0	0	16.50	0.00
	Water	38.7	0.387	0.01	0.00
Grand total					**3.23**
	MRM	19.3	0.193	5.50	1.06
R16S4	Pork rind	16	0.16	8.50	1.36
	Soya flour	4	0.04	16.50	0.66
	Water	49.9	0.499	0.01	0.00
Grand total					**3.08**
	MRM	4.1	0.041	5.50	0.22
R16S8	Pork rind	16	0.16	8.50	1.36
	Soya flour	8	0.08	16.50	1.32
	Water	61.2	0.612	0.01	0.01
Grand total					**2.91**

*Water - Unit cost of industrial or commercial water in Cape Town in the year 2010 was ≈ R9.18/kL (R0.00918/L ≈ R0.01/kg)

4. CONCLUSION

The preparations and experiments in Chapter 3 focused on the formulation of low-cost polony, while fixing the %LME of each treatment at 48% and a TME of less than 75%. The calculations for the nine treatments indicated that the cost of combining pork rind, soya protein, chicken MRM and water was highest (R4.54) for

Treatment 1 (R0S0) due to the high amount of chicken MRM used in the formulation, while treatment 9 (R16S8), with the least MRM, was the least expensive (R2.91).

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CHAPTER 4

PHYSICAL, CHEMICAL AND SENSORY CHARACTERISTICS OF POLONY

ABSTRACT

The effects of replacing chicken mechanically recovered meat (MRM) in polony with soya flour and pork rind proteins, while attempting to maintain the protein content constant at 10% for all products, were investigated. The levels of soya flour and pork rind used in replacement were 0, 4 and 8% and 0, 8 and 16% respectively. Hardness and gumminess increased up to 8% rind, followed by a decrease in both attributes at 16% rind. Cohesiveness increased, except for the treatment with 8% soya, of which the mean value decreased at 16% pork rind. Sliceability was used to determine the percentage of unbroken slices during slicing. Sliceability at both 3 mm and 2 mm improved, except for samples R0S8 and R16S8. Significant correlations of sliceability with cohesiveness and gumminess were found at 3 mm (P = 0.023, r = 0.739; P = 0.014, r = 0.773, respectively) and at 2 mm (P = 0.022, r = 0.742; P = 0.010, r = 0.796, respectively). For instrumental colour, lightness (L*) increased while redness (a*) decreased in all treatments, except for the sample with 8% soya (R16S8), of which the mean value increased at 16% rind level. Yellowness (b*) increased for samples with 8% soya (R0S8, R8S8 and R16S8), but decreased in samples with 0 and 4% soya (R8S0, R16S0, R0S4, R8S4 and R16S4). The water-holding capacity (WHC) improved in all treatments, except in treatments R0S0 and R0S8. In terms of pH, samples with 4 and 8% soya protein exhibited a constant pH at all rind levels, except for the treatment with 8% soya, of which the pH reduced at 16% rind. The pH of samples with 0% soya protein increased at all levels of pork rind. Polony pH was highly correlated with gumminess and cohesiveness (P = 0.016, r = 0.766 and P = 0.040, r = 0.689, respectively). As for the chemical results, fat reduced while moisture increased in all treatments. The hydroxyproline method was used to determine total collagen. In all treatments with added rind, the collagen content increased. Collagen was found to be significantly correlated with L* and a* (P = 0.004, r = 0.847 and P = 0.008, r = -0.808, respectively), while fat was highly correlated with hardness and L* (P = 0.019, r = 0.755; P = 0.018, r = -0.759, respectively). Sensory attributes, that is pink colour, colour intensity, salty taste, garlic flavour, polony flavour, spice flavour and firmness, decreased, while soya flavour, fatty mouthfeel and pastiness increased. Coarseness increased with soya levels but decreased with rind increase. Pink colour was positively correlated with a* (P = 0.020, r = 0.751) and negatively correlated with moisture (P < 0.0001, r = -0.976). Moisture was also highly correlated with colour intensity, firmness, pastiness and fatty mouthfeel (P < 0.0001, r = -0.975; P < 0.0001, r = -0.995; P < 0.0001, r = 0.972 and P < 0.0001, r = 0.978, respectively). Pastiness was also found to be correlated with hardness (P = 0.038, r = -0.693). Regarding consumer acceptability, sample R0S0 was the most preferred and acceptable, while R0S8 was the least preferred by consumers.

Keywords: Polony, mechanically recovered meat, soya, pork rind, chemical analyses, physical analyses, sensory analyses

1. INTRODUCTION

Good quality polony is characterised as having a pink colour and an acceptable polony flavour, and a juicy and firm texture. Some of the factors which lead to the development of these characteristics are the temperature and type of ingredients used during processing (Avil & Silva, 1999; Ibarz *et al*., 1999). For example, lean meat generally contributes positively towards a firmer bite and a stronger curing colour when used in high proportions (Feiner, 2006). Similarly, during cooking the action of heat on emulsified meat products denatures the fibrous proteins of meat, thereby affecting the texture through various chemical associations (Kuypers & Kurth, 1995). The denatured proteins do not only associate amongst themselves, but also with other components of polony such as fat and water. This interaction of protein with water and fat develops texture, mouthfeel and an overall sensation of lubricity (Giese, 1996). In the presence of added sodium nitrite, the pink colour of polony is also developed and stabilised during cooking (Aberle *et al*., 2001). The development of the aforementioned sensory and mechanical attributes of polony is of great significance for consumer choice and acceptance of food products, and consequently for the manufacturer (Mielnik *et al*., 2002; Yuste *et al*., 1999). The acceptability of meat after purchase is determined almost exclusively by the satisfaction derived from its consumption (Jeremiah *et al*., 1990).

Polony usually contains beef, veal and pork (Giese, 1992). However, lamb, goat, chicken, turkey, rabbit, venison and other game are also suitable for use in sausages, including polony. Beef and venison sausages are dark red, while veal, chicken and rabbit sausages are light in colour. Sausage flavour is affected more by spices than by the kind of meat used (Busboom *et al*., 2003). The use of chicken meat in the formulation of sausages is considered recent in the food industry, since it only started in the 1960s, when there was a strong movement to replace red meat with healthier white meat in industrialised countries, and also due to the lower price of white meat compared to other kinds of meat (Daros *et al*., 2005). The replacement of traditional sausage meat with chicken meat has resulted in products with new flavour and texture profiles. Typically, sausages made from chicken meat, besides being light in colour, have been found to have poor texture (Muguruma *et al*., 2003). Gums and nonmeat proteins are commonly used, with salt, to increase binding and improve the yield of meat products prepared with chicken mechanically recovered meat (MRM) (Comer & Allan-Wojtas, 1988). The addition of gums such as xanthan, carrageenan, locust bean gum and methylcellulose to meat products has been reported (Wallingford & Labuza, 1983; Foegeding & Ramsey, 1986; Mittal & Barbut, 1994). Guar gum was reported to bind free moisture and to retard shrinkage during cooking when used at 0.2 to 0.5%, whereas locust bean gum could impart a smooth texture to restructured meats and to sausages such as bologna (Dziezak, 1991). However, not all gums are compatible with meat batters. For example, xanthan gum significantly reduced hardness, even though it did not affect meat batter stability (Whiting, 1984; Foegeding & Ramsey, 1986). Lin *et al*. (1988) found that adding carboxymethyl cellulose to low-fat, high-added-water frankfurters decreased the textural parameters, with the exception of springiness and cohesiveness. Mittal and Barbut (1993) reported lower springiness in low-fat pork breakfast sausages made with carboxymethyl cellulose. Barbut and Mittal (1992) also reported that xanthan gum was detrimental to the textural and sensory properties of pork breakfast sausages.

In the current study, the soya and pork rind proteins were used to partially replace some of the chicken mechanically recovered meat (MRM) in the production of nine polony treatments, mainly to produce a cheaper product. This was followed by evaluating the effect of such replacements through various analyses. In this chapter, the methods used to analyse the nine treatments of polony for chemical, physical

and sensory attributes are outlined, and this is followed by the presentation and discussion of the results. The findings for consumer acceptability of the flavour and texture for five treatments of polony are also presented.

2. MATERIALS AND METHODS

The methods used for analysing the polony treatments can be categorised as chemical (proximate analyses and collagen analysis), physical, sensory and consumer acceptability. The data were analysed using both univariate and multivariate techniques.

The nine treatments samples which were analysed were R0S0, R0S4, R0S8. R8S0, R8S4, R8S8, R16S0, R16S4 and R16S8. The R and S represent pork rind and soya flour protein respectively, whereas the numbers represents the percentage of ingredients which were used in the treatments. The full composition of the nine treatments, as well as the procedures used in their production, have been described in detail in Chapter 3.

2.1. **Chemical analyses**

One polony sample from each of the nine treatments (stored at 4ºC) was selected for chemical analyses. Approximately 500 g was cut from each polony and homogenised. From the homogenised samples, six sub-samples were taken and used for proximate and collagen (hydroxyproline) analyses. The latter was used to analyse total collagen. Samples were analysed in duplicate. The analyses were replicated three times. AOAC official method number 976.05, 920.39, 934.01 and 942.05 were used for protein, fat, moisture and ash determination, respectively (AOAC, 2002). Total collagen content was determined by the procedures of Cross *et al*. (1973) and Hill (1966). Only the procedure for collagen will be discussed in this section, as the proximate methods have been presented in Chapter 3.

2.1.1. Collagen analysis

Collagen analysis was conducted in two major stages: preparation of the polony filtrate, followed by the analysis of the filtrate spectrophotometrically. These two stages are as follows:

2.1.1.1. Preparation of filtrate for analysis

To determine total collagen, 4.0 g of homogenised polony sample from each of the nine treatments was hydrolysed by 30 mL of 6 M HCl in a water bath set and working at 110°C for 13 h. Thereafter, the digested samples were removed from the water bath and cooled. To the cooled samples, 1.5 g of active carbon was added and stirred on a vortex. The carbon was then filtered out (Whatman 4 filter paper) and each sample of filtrate was collected in a 100 mL volumetric flask. From each of the duplicate sample filtrates, 1 mL was pipetted into test tubes, followed by pipetting of 1 mL of 10% KOH into each test tube containing the sample. The KOH neutralises the HCl acid. A blank tube containing 2 mL of distilled water was also prepared. Five standard solution test tubes, each containing L-hydroxyproline concentrations of 1.25, 2.5, 3.75, 5.0 and 7.5 µg/mL, were also prepared. Each test tube contained 2 mL of the standard solution. No KOH was added to the five standards and the blank sample.

2.1.1.2. Developing the filtrate colour

To all the test tubes with samples, including the five standards and blank sample, 1 mL of an oxidant solution containing chloramines-T was added, mixed on a vortex and allowed to sit for 20 min at room temperature. After 20 min, 1 mL of the colour reagent was added to all test tubes, followed by mixing on a vortex. The tests tubes were capped with aluminium foil and placed in a water bath at 60°C for 16 min. After 16 min, the test tubes were removed and the contents were mixed on a vortex, then allowed to cool to room temperature until a strong aromatic pink liquid with white salt residue formed in the tubes. Test tubes with samples from treatments R0S0 to R8S8 were diluted four times and the rest were diluted five times. The transparent pink liquid in the samples, the blank and standard test tubes was pippetted into micro-cuvettes and read by the UV/visible spectrophotometer (Model CE2021) at a wavelength of 560 nm.

2.2. Physical analyses

Colour, texture, pH and sliceability were measured using a CIELab colorimeter, an Instron Universal Testing Machine, a portable pH-meter and a polony slicer, respectively.

2.2.1. Colour measurement

Before the colour-guide 45°/0° colorimeter (Cat. No: 6805; BYK-Gardener, USA) was used, it was calibrated and the calibration was repeated from treatment to treatment. To measure colour, each side of a 2.5 cm thick slice of polony was used after allowing a blooming period of 2 min (Yang *et al*., 2007). Two readings were taken on each slice and this was repeated three times for all the treatments. The three slices which were used for colour measurement were immediately sealed in plastic bags and stored in a refrigerator (≈10°C) for 10 min before being used for the texture measurement.

2.2.2. Texture measurement

An Instron Universal Testing Machine (UTM; Model 3344) was used to perform texture profile analysis (TPA) with the Bluehill software. To measure texture, 3 x 2 cm diameter cores were cut out of each polony slice from each treatment, and this was replicated three times. The Instron UTM was fitted with a 5 kN load cell and the following settings were applied: crosshead speed of 200 mm/min and a compression of 50%. The speed and compression values were adapted from Flores *et al*. (2007), Caceres *et al*. (2004) and Cierach *et al*. (2009). Hardness (N), gumminess (N) and cohesiveness (no units) were measured.

2.2.3. pH and sliceability determination

To determine pH, 2 g of polony was homogenised with 10 mL of distilled water for each treatment (Cross *et al*., 1973; Hill, 1966). Duplicate readings were taken on a Crison 25 pH-meter for each polony treatment and this was replicated three times.

For each treatment, ten 3 mm thick slices and ten 2 mm thick slices were cut using a commercial polony slicer. These measurements were repeated twice. Sliceability was then calculated using the following formula adapted from Adams (2003):

$$\text{Sliceability} = \frac{(\text{Total no. of slices} - \text{no. of broken slices}) \times 100\%}{\text{Total no. of slices}}$$

where a broken slice was defined as a slice which crumbled during slicing

2.2.4. Water-holding capacity measurement

The water-holding capacity (WHC) was determined by the pressing method. Duplicate samples of 0.5 g were cut and weighed on labelled Lasec filter paper (grade 292, diameter 90 mm). The samples used were all kept in a fridge operating between 3 and 6°C to standardise the method. Only one sample was removed at a time for cutting and weighing. Each sample on the filter paper was placed between two Perspex plates and pressed at a pressure of 588 N for 60 s. The Perspex plates with the sample between them were then photographed. The amount of expressed fluid from the sample was calculated by finding the difference between the purge area (outer circle) and the inner circle. ImageJ software (http://rsbweb.nih.gov/ij/) was used to determine the polygon areas by tracing. The difference between the outer polygon drip area and the inner sample area was calculated. The area could be calculated in square pixels or square centimetres. If the area calculated was in square pixels there was a need to convert it into square centimetres. In this study, areas were calculated directly in square centimetres, as a calibration ruler had been included in the photograph.

2.3. Sensory analyses

Sensory analyses were conducted in two major stages, namely evaluation of samples by an expert panel, and training of the judges and analysis of the samples by the trained judges using descriptive analysis.

2.3.1. Expert panel analysis

For the expert panel analysis, five samples selected from the nine treatments were used to set up an initial questionnaire. The expert panel consisted of judges who were very familiar with polony and therefore did not need any training to evaluate the product. Eight expert panel judges were used to analyse polony samples. The reference standards used for the latter process were pork rind, pork rind emulsion, soy flour, corned beef, pork polony and chicken polony. The pork rind, pork rind emulsion and pork polony were used to assist the expert panel in identifying pork aroma and flavour; while soya flour was used to help the panel identify the soy aroma and flavour. Corned beef and chicken polony were also used in the latter process. Corned beef was used for identifying polony flavour and aroma, while chicken polony was used for identifying the flavour and aroma of cooked meat. R0S0, R0S4, R8S0, R8S4 and R16S8 were the treatment samples used by the expert panel to establish the respective sensory attributes associated with the polony samples. The attributes agreed on for appearance were brown pink, colour intensity and white spots; the flavour attributes garlic, spicy, soy and salt taste were agreed on; and for texture, firmness, pastiness and fatty mouthfeel were agreed on.

2.3.2. Descriptive analysis

Nine samples, one from each treatment, were used for training the panel. The same reference standards used by the expert judges were also used in the initial training session of the trained panel. Six judges were trained in generic descriptive sensory analysis according to Lawless and Heymann (1998). The steps are: train the judges, determine judge reproducibility/consistency and have judges evaluate the samples. Two training sessions were conducted on two separate days and each session lasted just over 2 h. During the training sessions the questionnaire was finalised and the judges agreed on scores for the respective attributes in each of the nine products.

After training, the trained panel analysed the samples using Compusense software (Compusense, Canada). The unstructured line scale, ranging from 0 to 100 was used to analyse each polony attribute. For each sample, a three-digit code was used as a blinding code. Each judge was randomly served a quarter slice of polony from each of the nine samples in each session. The samples were served at room temperature (21°C). The number of sessions conducted was four, each lasting 1 to 2 h. One session was carried out on each day, except for the last two sessions, which were done on the same day. Judge reproducibility was tested using Panel Check software (Panel Check software, Nofima, Norway).

2.4. Consumer acceptability

For consumer acceptability, five treatment samples, R0S0, R0S4, R0S8, R8S0 and R8S4, which were indicated by the trained panel to have high market potential, were used. The bipolar nine-point hedonic scale ranging from like extremely (9) to dislike extremely (1) was used for indicating the degree of liking of the flavour and texture of the polony samples (Lawless & Heymann, 1998). Each consumer (n = 100) was served one portion, which was one eighth of the full slice for all samples. Each served slice was about 1 cm thick. Samples were coded using three-digit numbers and were served randomly. Samples were evaluated by consumers at room temperature. Water was used for refreshing the mouth during testing of samples. The questionnaire used is shown in Annexure 1.

2.5. Statistical analysis of data

Both univariate and multivariate methods were used to analyse the polony data obtained in this research project. Univariate data analysis refers to any statistical technique used to analyse data that arises from one variable at a time, while multivariate methods refers to any statistical technique used to analyse data that arises from more than one variable at a time.

For the univariate method, analysis of variance (ANOVA) was performed on physical, sensory and consumer acceptability data using the General Linear Model (GLM) procedures of SAS statistical software version 9.1 (SAS Institute Inc., Cary, NC, USA). The Shapiro-Wilk test was performed to test for normality (Shapiro, 1965). The Student's t-least significant difference was calculated at the 5% level to compare treatment means (Ott, 1998). The chemical results were statistically analysed separately from the other results. This was done to determine if the objective of making treatments with 10 % protein was achieved. The student's t-least significant difference for chemical results was calculated at the 1% level to compare treatment means.

Principal component analysis (PCA), discriminant analysis (DA) and partial least square regression (PLS) were the multivariate methods carried out on the combined data of the chemical, physical, sensory and consumer acceptability analyses. The principle component analysis (PCA) shows differences in samples and which variables contribute most of these differences. It is also used to discover relationships between treatments and investigate sample patterns. Discriminant analysis (DA) is used to perceptually map the means of the sensory attributes to ascertain whether the treatments differ as total entities (Huberty, 1994). PLS is a technique that generalises and combines features from PCA and multiple regressions. It is particularly useful when there is need to predict a set of dependent variables from a (very) large set of independent variables (predictors). PLS can also be used to suggest where relationships might or might not exist (CAMO Software, 2010).

3. RESULTS AND DISCUSSION

3.1. Chemical analyses

Chemical analysis was done mainly with the intention of confirming that the treatment samples contained the calculated or theoretical values of nutrients as indicated in Table 5 of Chapter 3. In this subsection, the actual composition of the nine treatments of polony is presented.

3.1.1. Protein content of wet samples of polony

The polony samples for all nine treatments were formulated to contain 10% protein. The mean values of protein obtained after chemical analysis are presented in Table 2. Table 1 indicates that the difference between the means of the treatments was significant ($P < 0.0001$). Table 2 shows that the pre-determined value of 10% does not lie in the confidence interval for treatment R8S8, while it does for the other treatments. This means that the mean of treatment R8S8 was higher than the mean values of other treatments. This may have been due to problems with the raw material analysis and finished product analysis. This was especially experienced when analysing the pork rind emulsion which was extremely heterogeneous. However, this problem was minimised by more homogenisation of the samples before analysis. The effect of a higher value of protein in R8S8 will be discussed later.

3.1.2. Fat content of wet polony samples

The mean values of the total fat for the nine treatments of polony are shown in Tables 4. Table 3 shows that some polony treatments were different ($P < 0.0001$) in fat content. Generally, Table 4 shows that the fat content of the treatments decreased as the chicken MRM, which had a higher fat content, was being replaced with the low-fat ingredients (pork rind and soya). This is clearly seen in Table 4, where treatment R0S0, which had the highest MRM, is different ($P \leq 0.01$) from all the other samples and had the highest mean value of fat, while treatment R16S8, which had the least MRM, has the lowest fat content ($P \leq 0.01$) compared to all the other treatments. Kenawi *et al*. (2009) found similar results when low fat soya flour and/or mung bean powder was used as a meat extender in buffalo meat patties. Their results showed that the use of low fat soya flour or mung bean powder at a level of 10% reduced the fat content of the meat patties. For the effect of rind, Abiola and Adegbaju (2001) also observed that the level of fat in pork sausages decreased with an increase in the levels of rind used to replace pork back fat.

3.1.3. Moisture content of wet polony samples

The ANOVA in Table 5 indicates that the F value for the polony treatments was significant ($P < 0.0001$), meaning that some treatments were different in terms of moisture. In Table 6 it is noticeable that, as more MRM was being replaced with rind and soya protein, the moisture content of the treatment increased. Treatment R0S0 had the least moisture content as it had the most MRM, while R16S8 had the highest moisture, as most of the MRM had been replaced with soya and rind. Similar results were obtained by Visessanguan *et al*. (2005), who noted that an incremental addition of cooked pork rind resulted in higher moisture values of Nham, a fermented Thai pork sausage. In another study, Abiola and Adegbaju (2001) also observed that the increase of rind in pork sausage increased moisture and reduced fat.

3.1.4. Ash content of wet polony samples

A significant ($P < 0.0001$) F value (Table 7) indicates that the treatment means for ash were not equal. Table 8 indicates that the content of ash for treatments with more rind was lower compared to treatments with no rind and those combined with soya. These results show that soya increases the ash content while rind decreases the ash content. The tendency of the ash content to reduce with an increase in pork rind was also observed by Abiola and Adegbaju (2001).

3.1.5. Effect of pork rind on hydroxyproline content

The significance ($P < 0.0001$) of the F value in Table 9 illustrates that some treatments were not equal in terms of collagen content. As expected and shown in Table 10, treatments in which more rind (R16S0, R16S4 and R16S8) was used to replace MRM had the highest hydroxyproline or total collagen content, while those with less (R8S0, R8S8 and R8S8) or no added pork rind had less total collagen (R0S0, R0S4 and R0S8). The only source of collagen for the latter samples was MRM.

Table 1 ANOVA for protein in nine treatments of wet polony samples.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Treatment	8	3.13718015	0.39214752	7.46	< 0.0001
Error	45	2.3660795	0.05257954		
Corrected total	53	5.50325965			

Table 2 Confidence intervals for mean values of protein in nine treatments of wet polony samples.

Treatment	Mean (%)	Simultaneous 99% confidence limits
R8S8	10.5	10.16 – 10.82
R16S0	10.3	9.97 – 10.62
R8S4	10.3	9.93 – 10.58
R8S0	10.2	9.85 – 10.51
R0S8	10.0	9.71 – 10.37
R16S8	10.0	9.64 – 10.29
R0S4	9.9	9.62 – 10.27
R16S4	9.8	9.48 – 10.14
R0S0	9.7	9.35 – 10.01

Table 3 ANOVA for fat in nine treatments of wet polony samples.

Source	DF	Sum of squares	Mean square	F value	Pr > F
Treatment	8	544.9539819	68.1192477	296.65	< 0.0001
Error	45	10.3334368	0.2296319		
Corrected total	53	555.2874188			

Table 4 Comparison of mean values of fat in nine treatments of wet samples of polony.

Treatment	Mean (%)
R0S0	13.2a
R8S0	11.8b
R0S4	11.5b
R0S8	9.0c
R16S0	8.8c
R8S4	8.3c
R16S4	6.2d
R8S8	5.6d
R16S8	2.6e
	LSD (*P* = 0.01) = 1.09

Means with same letter are not significantly different at the 1% level of significance

LSD – least significant difference

Table 5 ANOVA for moisture in nine treatments of wet polony samples.

Source	DF	Sum of squares	Mean square	F value	Pr > F
Treatment	8	313.0633521	39.132919	505.75	< 0.0001
Error	45	3.4831567	0.0774035		
Corrected total	53	316.5465088			

Table 6 Comparison of mean values of moisture in nine treatments of polony wet samples.

Treatment	Mean (%)
R16S8	71.9a
R16S4	70.1b
R16S0	69.8bc
R8S8	69.2c
R8S4	67.6d
R8S0	67.1d
R0S8	65.7e
R0S4	65.2e
R0S0	64.2f
	LSD (*P* = 0.01) = 0.63

Means with same letter are not significantly different at the 1% level of significance

LSD – least significant difference

Table 7 ANOVA for ash in nine treatments of wet polony samples.

Source	DF	Sum of squares	Mean square	F value	Pr > F
Treatment	8	2.50610033	0.3132625	20.96	< 0.0001
Error	45	0.672429	0.0149429		
Corrected total	53	3.17852933			

Table 8 Comparison of mean values of ash in nine treatments of wet samples of polony.

Treatment	Mean (%)
R0S8	3.1a
R8S8	2.9ab
R0S4	2.8bc
R8S4	2.8bc
R0S0	2.7bc
R16S8	2.6cd
R16S4	2.5cd
R8S0	2.5cd
R16S0	2.4d
	LSD (*P* = 0.01) = 0.28

Means with same letter are not significantly different at the 1% level of significance

LSD – least significant difference

Table 9 ANOVA for total collagen in nine treatments of wet polony samples.

Source	DF	Sum of squares	Mean square	F value	Pr > F
Treatment	8	768.2275356	96.0284419	323.81	< 0.0001
Error	45	13.344963	0.2965547		
Corrected total	53	781.5724986			

Table 10 Comparison of mean values of total collagen in nine treatments of wet samples of polony.

Treatment	Mean (mg/g)
R16S0	17.9a
R16S8	17.8a
R16S4	17.6a
R8S8	14.2b
R8S0	13.9b
R8S4	13.9b
R0S0	9.6c
R0S4	9.4c
R0S8	7.2d
	LSD (*P* = 0.01) = 1.24

Means with same letter are not significantly different at the 1% level of significance

LSD – least significant difference

3.2. Physical analyses

The variables measured were colour, water-holding capacity, texture and pH of the polony. For colour, the lightness (L*), redness (a*) and yellowness (b*) were determined.

3.2.1. Instrumental colour

The ANOVA for the analysed data on L* indicated that there was a significant interaction ($P < 0.0001$) between pork rind and soya flour, as indicated in Table 11. The effect of replacing MRM with rind and soya on L* is presented in Figure 1. The results show that the lowest mean value was for the control (R0S0), and it differed significantly ($P \leq 0.05$) from the other treatments. Both soya and rind proteins are white in colour. As more of one or a combination of these proteins was used to replace MRM in the respective polony treatments, the whiter the treatment samples became. The increase in whiteness is shown by the increase of the L* value in Figure 1 as rind and soya levels increased. These findings agree with Dzudie *et al*. (2002), who noted that sausages extended with 5, 7.5 and 10% common bean flour (CBF) were lighter than the control, which had no CBF. In another study, Fojtik and Mandigo (1998) used two different levels of 10 and 20% pork skins (pork rinds) in combination with higher quantities of water in fresh pork sausages. Their results also showed that pork sausages became lighter. The products became lighter due to the dilution of lean meat blood pigments by increased pork skin and water levels. In a study that was done by Dingstad *et al*. (2005), it was noted that lightness is a main attribute that correlates well with consumer acceptability. They observed that at least 60% of consumers were willing to buy sausage when L* was between 62.3 and 68.5. However, in South Africa, the values of L* acceptable to consumers have not yet been established.

In Table 12, significant interaction ($P < 0.0001$) can be observed between soya and rind (rind x soya). It can further be observed that the mean values of redness (a*) decreased with an increase in both rind and soya proteins. Chicken MRM contains red pigments of blood (myoglobin and haemoglobin). The replacement of MRM with white proteins (rind and soya) reduced the red colour of the polony treatments. This is shown in Figure 2, where redness decreased with an increase in soya or rind or their combination. These findings agree with what Dzudie *et al*. (2002) found. They observed that samples of sausages substituted with 7.5 and 10% common bean flour had lower degree of redness. Similarly, Akesowan (2008) found that the use of 1.5% or more soya protein isolate caused pork sausages to be less red. However, the current results contradict what Fojtik and Mandigo (1998) found. In their study they discovered that the use of higher levels of pork skin in sausage formulation did not affect redness.

The results for yellowness (b*) are shown in Figure 3 and Table 13. An interaction ($P < 0.0001$) between soya and rind was also observed for yellowness (Table 13). The means of treatment samples at 0% pork rind were not different ($P > 0.05$) in yellowness (b*), while the mean value of S8 at 8% pork rind differed ($P \leq 0.05$) from the other two (Figure 3). This difference was caused by the higher protein content in treatment R8S8. At the level of 16% rind, all the sample means differed significantly from each other ($P \leq 0.05$). Generally, the mean values of b* for samples with 8% soya (S8) increased, while samples with 0% (S0) and 4% soya (S4) decreased up to the level of 8% rind. However, the b* value of S4 slightly increased at the level of 16% rind while that of S0 did not significantly increase. These results shows that soya increased yellowness in treatments it was added. This was probably due to the soya flour which was slightly yellow, though it generally appeared white. In a study by Akesowan (2008), in which 1.5% or more soya protein was used to make pork sausages, it was observed that the sausages became more yellow. Similarly, Dzudie *et al*. (2002) found that samples were more yellow when levels of 7.5 and 10% of common bean flour were used in extending sausages.

3.2.2. Instrumental texture

A significant interaction (P = 0.0230) of added soya and rind was observed on polony samples for hardness (Table 14). As can be seen in Figure 4, the mean values of S0 and S4 were higher and significantly different from the mean of S8. This shows that samples with 0% rind but containing a higher level of soya (8%) are softer than those with 0 and 4% soya at the same rind level (0%). When the level of rind increased from 0 to 8%, treatments with 0% soya (S0) and 4% soya (S4) increased in hardness, while S8 decreased. However, when the level of rind increased from 8 to 16%, all treatments became softer. Generally, these results indicate that the replacement of MRM with rind levels of up to 8% and soya levels of up to 4% increased the hardness of the polony treatments, while treatments with 8% soya were softer at all levels of rind. Similar results were obtained for gumminess, as shown in Table 15 and Figure 5. The present results, which showed an increase in hardness up to 8% rind, are not consistent with those reported by other researchers. Dawkins *et al*. (2001), Ho *et al*. (1997) and Prabhu and Sebranek (1997) reported that the addition of oat bran, soya protein or starch decreased the hardness of sausage products. On a positive note, Ho *et al*. (1997) reported that the moderate decrease of hardness and gumminess was actually an improvement in texture. In the study done by the latter, tofu powder (one of the soybean products) was used in lean frankfurters to demonstrate the reduction of hardness and gumminess. Troutt *et al*. (1992) further suggested that a decrease in the hardness of sausages by the addition of texture-modifying ingredients may be associated with the water-binding properties of the ingredient, such as soya protein, oat bran and starch, which may help to absorb and retain moisture. Kerr *et al*. (2005) also suggested that the presence of texture-modifying extenders may reduce binding among the proteins, rather than the water-binding property of the extender. The influence of texture-modifying agents on hardness associated with the water-binding property of the agents is complicated and remains in dispute (Yang *et al*., 2007). According to Chambers and Bowers (1993), hardness is the most important attribute to the consumers because it decides the commercial value of meat. According to Dingstad *et al*. (2005), sausage with a hardness of 47.3 N and above will have at least 60% of consumers willing to buy it. However, higher values for the parameter do not necessarily mean better quality. There is a cut-off point above which the texture of comminuted meat products would be unacceptable (Yu & Yeang, 1993). According to this finding, all the polony treatments made in this project might not be very acceptable to consumers, as most of the mean values for hardness were below 47.3 N. However, the cut-off point for South African consumers is unknown.

The F value in Table 16 for the attribute of cohesiveness was significant (P = 0.0052), indicating that there was an interaction between rind and soya. As shown in Figure 6, the mean values of cohesiveness for S0 and S4 at 0% pork rind were different ($P \leq 0.05$) from the mean of S8. At the level of 8% pork rind, all treatment means did not differ ($P > 0.05$) for the attribute of cohesiveness, while at 16% rind level, the mean value of S8 reduced significantly. In general, the results in Figure 6 show that the replacement of MRM with soya increased the cohesiveness of polony treatments at all levels of rind, except for products with 8% soya (S8), which decreased at the 16% level of rind. These findings also show that the addition of binding aids such as soya and rind improve cohesiveness, as long as too much is not used (Ranken, 2000). In a study conducted by Chin *et al*. (1999), they established that the use of incremental levels of soy protein below 3% decreased the cohesiveness of low-fat meat products. The current results disagree with the findings of Chin *et al*. (1999) because some of the treatments of polony in which soy protein was used alone, for instance at

the level of 4%, showed that cohesiveness increased. A possible explanation might be the difference in the fat content of the products used in their study and in the current study.

3.2.3. pH

A significant interaction ($P < 0.0001$) of soya and pork rind occurred in some treatments (Table 17). At the level of 16% pork rind, the pH of polony with 8% soya (S8) was significantly lower than that of the other treatments, as illustrated in Figure 7. The results in Figure 7 also show that all the polony treatments were acidic. At these pH values, the possible cause of spoilage in polony which has been pasteurised during cooking are moulds. Treatments represented by S8 which has the lowest pH has a higher chance of spoilage during storage than treatments shown by S4 and S0 which had higher pH values.

For treatments with 4% soya (S4), no significant change was observed in the pH of the treatments at all levels of rind. For S0 there was an increase in pH at all levels of rind used in the study. The current results of S0 which showed an increase in pH as rind increased are similar to the results of Fotjik and Mandigo (1998). Their research revealed that the incorporation of pork skin (with a pH of 7.06) in fresh pork sausages caused an increase in the pH. As for the S4 results, similar findings were observed by Porcella *et al*. (2001). According to their study, the addition of soya protein isolate to vacuum-packaged chorizos did not increase the pH significantly.

3.2.4. The water-holding capacity

The ANOVA (Table 18) shows that soya and rind interacted significantly ($P < 0.0001$). As illustrated in Figure 8, all treatments with 8 and 16% pork rind had better water-holding capacity (WHC) than those in which soya was used singly to replace MRM (except for S4). The treatments with good WHC had a mean area of 0 cm^2. This area shows that no expressible fluid (water and fat) came out of the polony samples after being pressed. However, treatments with 0% soya (S0) and 8% soya (S8) at 0% rind lost some fluid upon being pressed, which is an indication of poor WHC. The latter results cannot be explained – namely why 4% soya improved WHC while 8% soya did not at 0% rind. A possible explanation may be that the formulation did not contain sufficient free water to properly hydrate the soya before cooking, whereas with higher levels of rind addition, the amount of free water for soya hydration was sufficient. This needs to be investigated further. Yada (2004) recommended that collagen (in the form of gelatine) can result in meat products with better binding strength and juiciness if used at levels not exceeding 10%. Contrary to this recommendation, the current study showed that pork rind, a high-collagen material, improved WHC at a level higher (16%) than 10%. It is also essential to note that both samples (S0 and S8) which had poor WHC had the same pH at 0% rind, as indicated in Figure 7.

3.2.5. Sliceability

Sliceability was determined by cutting slices of 3 mm and 2 mm using an industrial polony slicer. The control treatment (R0S0) had 100% sliceability at both 3 and 2 mm slice thickness (Figure 14). At 3 and 2 mm slice thicknesses, the sliceability of treatments R0S4 and R0S8 was reduced, but the reduction was higher at 2 mm. The decrease in sliceability of R0S4 and R0S8 at both slice thicknesses could be attributed to the increase in soya levels. Ramirez-Sua'rez and Xiong (2003) suggested that most of the non-meat proteins which are used for replacement undergo very little structural changes under normal meat-processing conditions (65 – 73°C, pH 5.5 – 6.0, and ionic strength 0.1 – 0.6 M). For instance, glycinin from soy protein

denatures between 90 – 95°C, which is a temperature range beyond normal processing temperatures (Ramirez-Sua'rez & Xiong, 2003). Hence, there could be a lack of interaction between non-meat proteins and muscle proteins in processed meat products. As a result, these non-meat proteins do not participate in the protein structure, or even negatively affect texture by the diluting effect or by interference with the gelation of the myofibrillar proteins (Fogeding & Lanier, 1989). The sliceability for the control (R0S0) and treatments R8S0, R8S4, R8S8, R16S0 and R16S4 was 100% at 3 mm slice thickness, and was poorest (40%) for sample R16S8. Similarly, sliceability was 100% for the control, R8S0, R8S4 and R8S8, but was poorest (0%) for the R16S8 samples at 2 mm. The reason for this poor texture of R16S8 was possibly due to the high level of soya used in combination with a high pork rind level. Higher levels of soya may negatively affect texture, as suggested by Ramirez-Sua'rez and Xiong (2003).

Table 11 The lightness ANOVA showing the level of significance for the main effects and interaction effects of pork rind and soya proteins in polony.

Source	DF	Type I SS	Mean square	F value	Pr > F
Batch	2	0.1013407	0.0506704	0.48	0.6267
Rind	2	232.1757630	116.0878815	1102.53	< 0.0001
Soy	2	14.1563463	7.0781731	67.22	< 0.0001
Rind x soya	4	30.1237370	7.5309343	71.52	< 0.0001

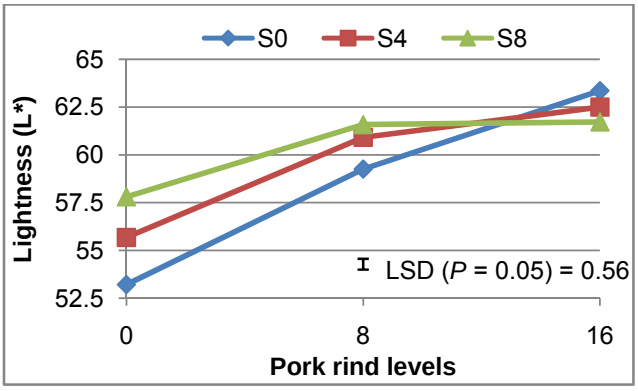


Figure 1 Mean values of lightness for nine treatments of wet polony samples manufactured with three levels of pork rind (0, 8 & 16%) and soya levels (0, 4 & 8%, shown as S0, S4 & S8).

Table 12 The ANOVA showing the level of significance for the main effects and interaction effects of pork rind and soya proteins on polony redness.

Source	DF	Type I SS	Mean square	F value	Pr > F
Batch	2	0.12212407	0.06106204	1.53	0.2471
Rind	2	12.09711852	6.04855926	151.33	< 0.0001
Soy	2	1.20136852	0.60068426	15.03	0.0002
Rind x soy	4	2.18050370	0.54512593	13.64	< 0.0001

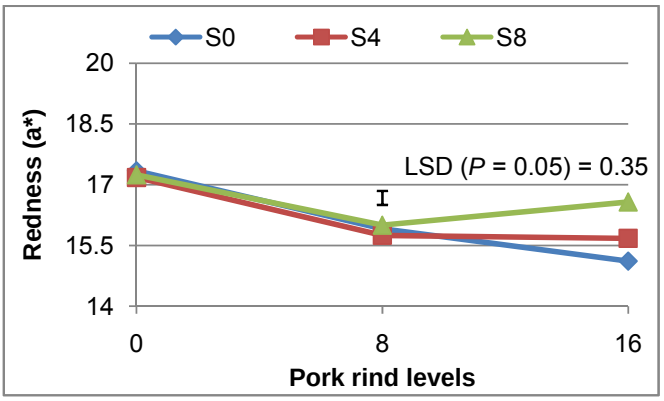


Figure 2 Mean values of redness for nine treatments of wet polony samples manufactured with three levels of pork rind (0, 8 & 16%) and soya levels (0, 4 & 8%, shown as S0, S4 & S8).

Table 13 The yellowness ANOVA showing the level of significance for the main effects and interaction effects of pork rind and soya proteins.

Source	DF	Type I SS	Mean square	F value	Pr > F
Batch	2	0.29833519	0.14916759	1.44	0.2661
Rind	2	6.25933519	3.12966759	30.21	< 0.0001
Soy	2	11.89507963	5.94753981	57.41	< 0.0001
Rind x soy	4	8.40177037	2.10044259	20.28	< 0.0001

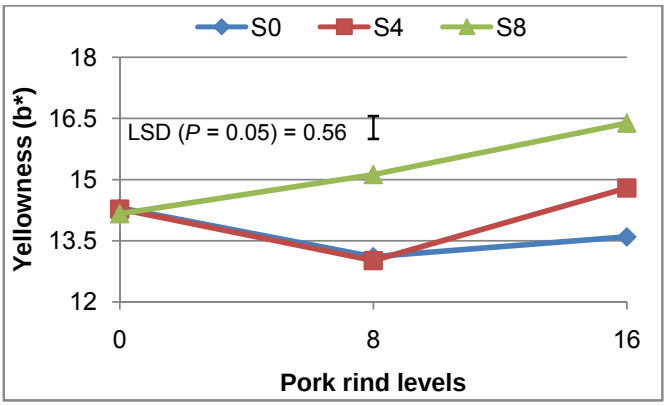


Figure 3 Mean values of yellowness for nine treatments of wet polony samples made with three levels of pork rind (0, 8 & 16%) and soya levels (0, 4 & 8%, shown as S0, S4 & S8).

Table 14 ANOVA for hardness showing the level of significance for the main effects and interaction effects of pork rind and soya proteins.

Source	DF	Type I SS	Mean square	F value	Pr > F
Batch	2	0.4100156	0.2050078	0.07	0.9299
Rind	2	181.5302848	90.7651424	32.30	< 0.0001
Soy	2	203.2500996	101.6250498	36.16	< 0.0001
Rind x soy	4	42.9577128	10.7394282	3.82	0.0230

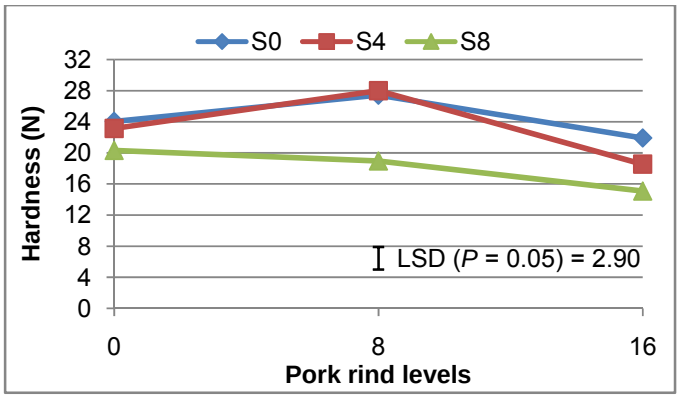


Figure 4 Mean values of hardness in nine treatments of wet polony samples made with three levels of pork rind (0, 8 & 16%) and soya levels (0, 4 & 8%, shown as S0, S4 & S8).

Table 15 ANOVA for gumminess showing the level of significance for the main effects and interaction effects of pork rind and soya proteins.

Source	DF	Type I SS	Mean square	F value	Pr > F
Batch	2	0.0328423	0.0164211	0.02	0.9786
Rind	2	59.1898712	29.5949356	39.04	< 0.0001
Soy	2	127.8310700	63.9155350	84.32	< 0.0001
Rind x soy	4	13.0349259	3.2587315	4.30	0.0150

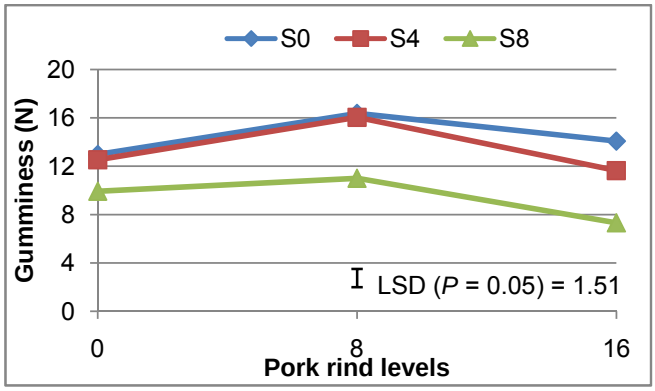


Figure 5 Mean values of gumminess in nine treatments of wet polony samples with three levels of pork rind (0, 8 & 16%) and soya levels (0, 4 & 8%, shown as S0, S4 & S8).

Table 16 The ANOVA of cohesiveness showing the level of significance for the main effects and interaction effects of pork rind and soya proteins.

Source	DF	Type I SS	Mean square	F value	Pr > F
Batch	2	0.00040850	0.00020425	0.20	0.8225
Rind	2	0.02338290	0.01169145	11.32	0.0009
Soy	2	0.03224357	0.01612179	15.61	0.0002
Rind x soy	4	0.02310816	0.00577704	5.59	0.0052

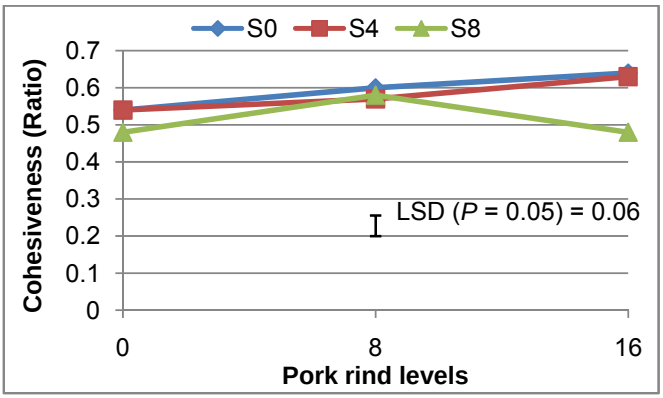


Figure 6 Mean values of cohesiveness in nine treatments of wet polony samples made with three levels of pork rind (0, 8 & 16%) and soya levels (0, 4 & 8%, shown as S0, S4 & S8).

Table 17 The ANOVA for polony pH showing the level of significance for the main effects and interaction effects of pork rind and soya proteins.

Source	DF	Type I SS	Mean square	F value	Pr > F
Batch	2	0.1013407	0.0506704	0.48	0.6267
Rind	2	232.1757630	116.0878815	1102.53	< 0.0001
Soy	2	14.1563463	7.0781731	67.22	< 0.0001
Rind x soy	4	30.1237370	7.5309343	71.52	< 0.0001

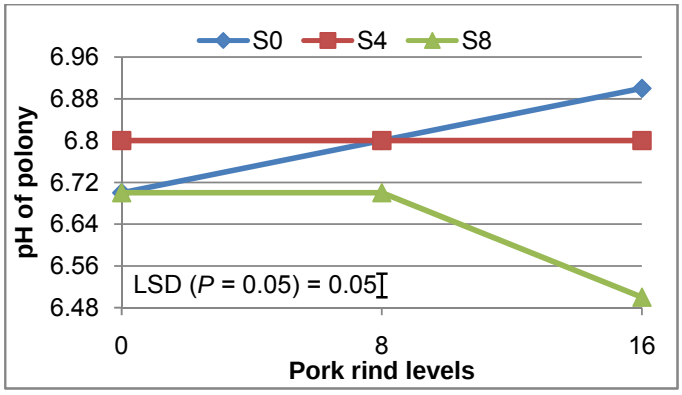


Figure 7 Mean values of polony pH for nine treatments of wet polony samples made with three levels of pork rind (0, 8 & 16%) and soya levels (0, 4 & 8%, shown as S0, S4 & S8).

Table 18 The ANOVA of WHC showing the level of significance for the main effects and interaction effects of pork rind and soya proteins.

Source	DF	Type I SS	Mean square	F value	Pr > F
Batch	2	0.03726202	0.0186310	1.06	0.3689
Rind	2	13.10000757	6.55000379	373.43	< 0.0001
Soy	2	3.95964691	1.97982345	112.87	< 0.0001
Rind x soy	4	7.91929381	1.97982345	112.87	< 0.0001

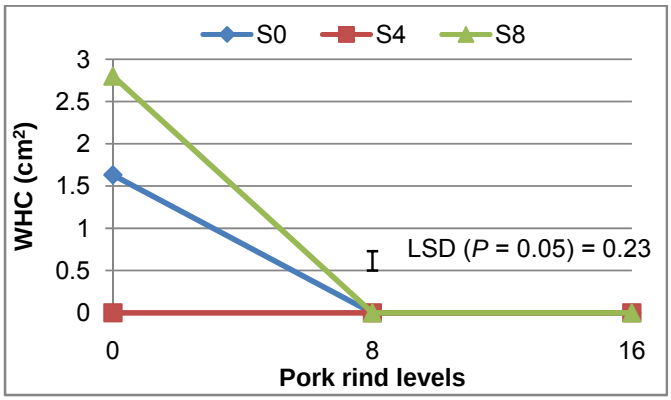


Figure 8 Mean values of water-holding capacity (WHC) of nine treatments of wet samples manufactured with three levels of pork rind (0, 8 & 16%) and soya levels (0, 4 & 8%, shown as S0, S4 & S8).

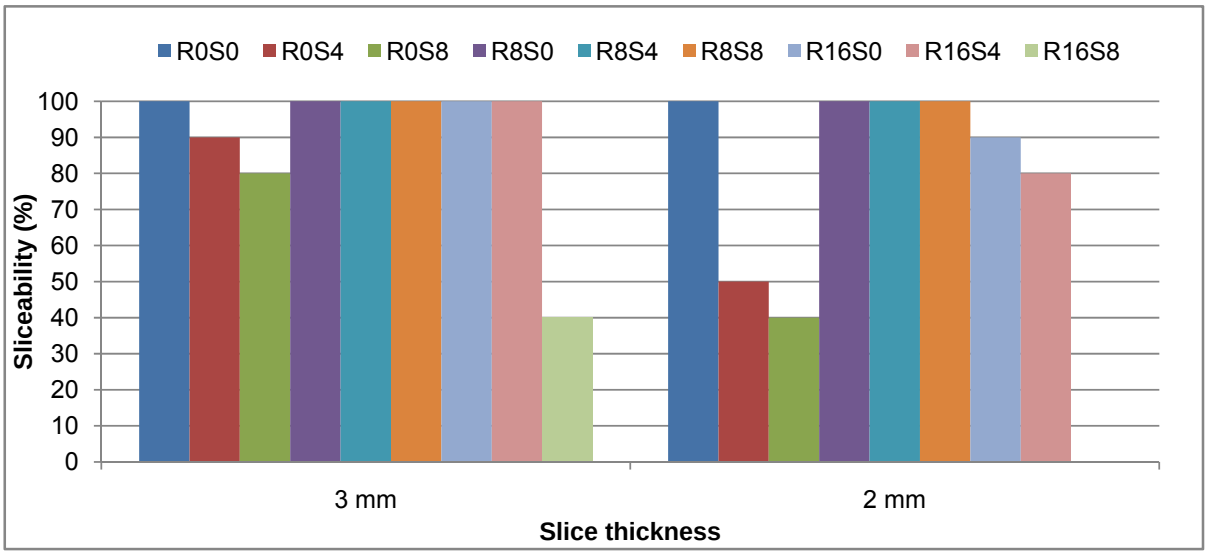


Figure 9 Mean values of sliceability of polony for nine treatments with three levels of pork rind (0, 8 & 16%) and soya levels (0, 4 & 8%) at slicing thickness of 3 mm and 2 mm.

3.3. Sensory analyses

The results for the sensory attributes are discussed as interaction and main effects in the subsection that follows.

3.3.1. Interaction effects for sensory attributes

Significant interaction effects between soya and pork rind proteins were noted for the attributes of brown pink colour (P = 0.0117), white spots (P < 0.0001), salty taste (P = 0.0051), soya flavour (P < 0.0001), garlic flavour (P = 0.0264), firmness (P = 0.0484), pasty (P = 0.0005) and fatty mouthfeel (P = 0.0003).

The effect of replacing MRM with soya and pork rind significantly ($P \leq 0.05$) decreased the pink colour of all treatments compared to the control (R0S0; Figure 10). However, samples R0S4 and R0S8 did not differ ($P > 0.05$) from each other. Similarly, samples R8S8 and R16S0 did not differ significantly from each other. For white spots, samples R0S4 and R0S8 did not differ ($P > 0.05$) from the control, while the rest differed ($P \leq 0.05$). The present findings for pink colour are consistent with Abiola and Adegbaju (2001), who reported that, when pork back fat was replaced with rind levels of 0, 33, 66 and 100%, the colour of pork sausages decreased correspondingly. In treatments in which rind was added (R8S0, R8S4, R8S8, R16S0, R16S4 and R16S8), white spots were observed. The white spots were particles of rind which resulted from incomplete emulsification of pork rind by the bowl cutter. However, the negative attribute of white spots can be rectified by extensive chopping of the raw batter of the treatments containing pork rind. The negative effect of MRM replacement with rind and soya on the pink colour of polony can be counteracted by adding more dye during the emulsification stage. The dye, such as erythrosine BS, can be added to enhance the pink colour of polony up to the maximum level of 30 mg/Kg of the product (Department of Health, 1996).

The results in Figure 11 shows that the mean values of both salty taste and garlic flavour decreased compared to the control as more MRM was being replaced by increasing levels of soya flour and pork rind, while the mean values of soya flavour increased. Matulis *et al*. (1995) established that the flavours produced by soya proteins in frankfurters (soya levels used ranged from 0 to 3%) masked the intensity of other flavours. Similarly, Chin *et al*. (1999) established that levels of less than 3% soya protein decreased juiciness and saltiness in low-fat meat products. For the samples which had no soya (R0S0, R8S0 and R16S0), the scores on soya flavour where expected to be zero; however, that was not the case. It can be concluded that the addition of rind in R8S0 and R16S0 resulted in a flavour similar to that of soya. Since the reduction of salty taste and garlic flavour is undesirable in polony substituted with soya and rind, more salt and garlic can be added in the formulations of polony to counter the effect of meat substitutes. In the present study, the amount of salt which was added in all treatments was 1.8%, while the levels of spices ranged from 0.05% to 0.2%. The commonly used concentrations of salt are 2 to 3%. Higher levels of salt (5%) are not acceptable from an organoleptic point of view (Feiner, 2006). Garlic can be added at 3 – 5 g/kg in order to enhance the flavour of polony substituted with rind and soya (Feiner, 2006).

For sensory texture, the attributes analysed were firmness, pastiness and fatty mouthfeel (Figure 12). All treatments decreased in firmness due to an increase of soya and rind proteins, and all treatment mean values differed ($P \leq 0.05$) from the control, except for R0S4. For both pastiness and fatty mouthfeel, the mean scores for texture increased in all samples compared to the control treatment. However, for both pasty and fatty mouthfeel, texture mean scores for samples R0S4 and R0S8 did not differ ($P > 0.05$) from the control, while the rest did. Feiner (2006) highlighted that the replacing of lean meat with soya protein and water, as was done in the present study, affects texture and firmness because the replaced meat proteins contribute positively to the named parameters. In Figure 12 it can clearly be seen that an increased replacement of chicken MRM with pork rind and soya reduced firmness and increased the sensory textural attributes of pastiness and fatty mouthfeel in all the polony treatments, except for the control.

The texture attributes of polony can be improved by adding hydrocolloid gums such as carrageenan, alginate, guar gum and locust bean gum (LBG). Carrageenan for instance, improves moisture retention, slicing properties, mouthfeel and water-holding capacity of processed meat products (Imeson, 2000; Zou *et al*., 2010). According to R2527 of 1987, hydrocolloids can be added up to 3 000 mg/Kg of the meat product (Department of Health, 1987).

3.3.2. Main effects results for sensory attributes

Where no interaction ($P > 0.05$) between pork rind and soya proteins was observed, only the main effects for the sensory attributes colour intensity, coarse texture, polony flavour and spicy flavour are discussed .

In Figure 13 (a), the mean values of the colour intensity for polony decreased dramatically as more MRM was being substituted with increasing levels of pork rind, and all the mean values differed ($P \leq 0.05$). Similarly, as the levels of soya increased (Figure 13 (b)), the mean values for colour intensity reduced and the means for colour intensity were different ($P \leq 0.05$) at all soya levels. These results showed that the pork rind and soya each reduced colour intensity as their levels increased, but the reduction was higher for pork rind than with soya protein. Abiola and Adegbaju (2001) also observed that the colour of fresh pork sausage generally declined as rind increased (levels used were 0, 33, 66 and 100%). The decrease in the colour intensity in the presence of either soya protein or pork rind could possibly have been due to the dilution of the chicken meat blood pigments by the extenders and water which were added (Fotjik & Mandigo, 1998). The solution for the negative effect of both soya and rind on colour intensity lies in adding more pink-enhancing ingredients, as discussed.

It was also noted that both polony and spicy flavours declined with an increase in both pork rind and soya protein, but the decrease in the flavours was greater for pork rind levels (Figures 14 and 15, respectively). The latter results contradict the findings of Decker *et al*. (1986), who noted that incremental levels of soya protein isolate added to frankfurters up to about 3% had no effect on spiciness, but rather decreased the meaty flavour. The explanation for this contradiction is that higher soya levels (4 and 8%) tend to mask both spiciness and polony flavours, while lower levels (< 3%) seem not to. As for the effect of pork rind on flavour, Abiola and Adegbaju (2001) found that the use of 0, 33, 66 and 100% pork rind in fresh pork sausage decreased the flavour of the sausages. In order to counteract the negative effects of soya or pork rind on polony flavour, more spices, including hydrolysed vegetable protein (HVP), can be added. HVPs can be from plants such as soy, maize or gluten. Soya protein is the most preferred source of HVP. To make HVP, soya protein is broken down into amino acids and peptides by hydrochloric acid, followed by neutralising the acid. The HVP slurry is then heated to develop flavours through the reactions of amino acids. Generally, spices, including HVPs are added at the rate of 3 – 5 g/kg of sausage (Feiner, 2006).

The mean values for coarse texture decreased with an increase in pork rind levels, and the mean scores for this textural attribute differed ($P \leq 0.05$) at rind levels of 0 and 8% (Figure 16 (a)). However, coarseness at rind levels of 8 and 16% did not differ ($P > 0.05$). Figure 16 (b) shows that the average values of coarseness increased with an increase in soya levels, and the mean at 8% soya differed ($P \leq 0.05$) from the other two. Generally, the results in Figure 16 reveal that sensory coarse texture decreased with an increase in pork rind levels and increased with an increase in soya level.

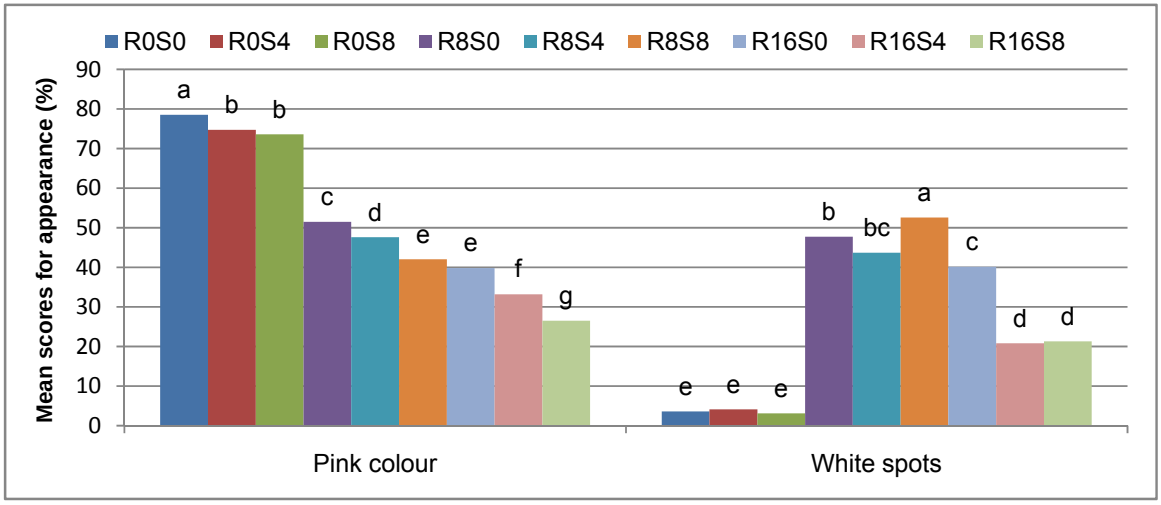


Figure 10 Mean scores for pink colour and white spots of nine treatments of polony manufactured with three levels of pork rind (0, 8 & 16%) and soya (0, 4 & 8%). Means within each sensory attribute with the same letter do not differ significantly ($P > 0.05$).

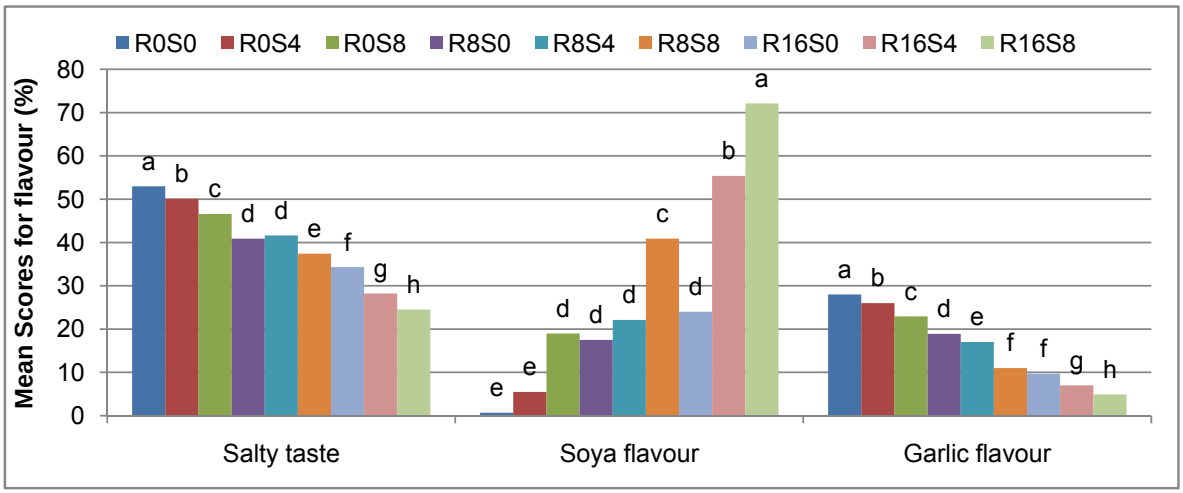


Figure 11 Mean scores for salty taste, soya flavour and white garlic flavour of nine treatments of polony manufactured with three levels of pork rind (0, 8 & 16%) and soya (0, 4 & 8%). Means within each sensory attribute with the same letter do not differ significantly ($P > 0.05$).

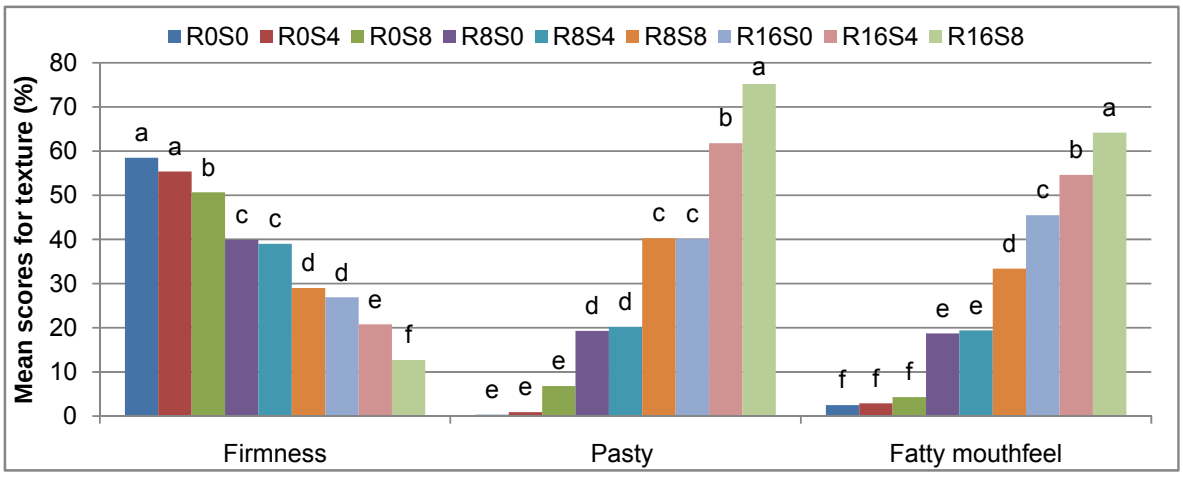
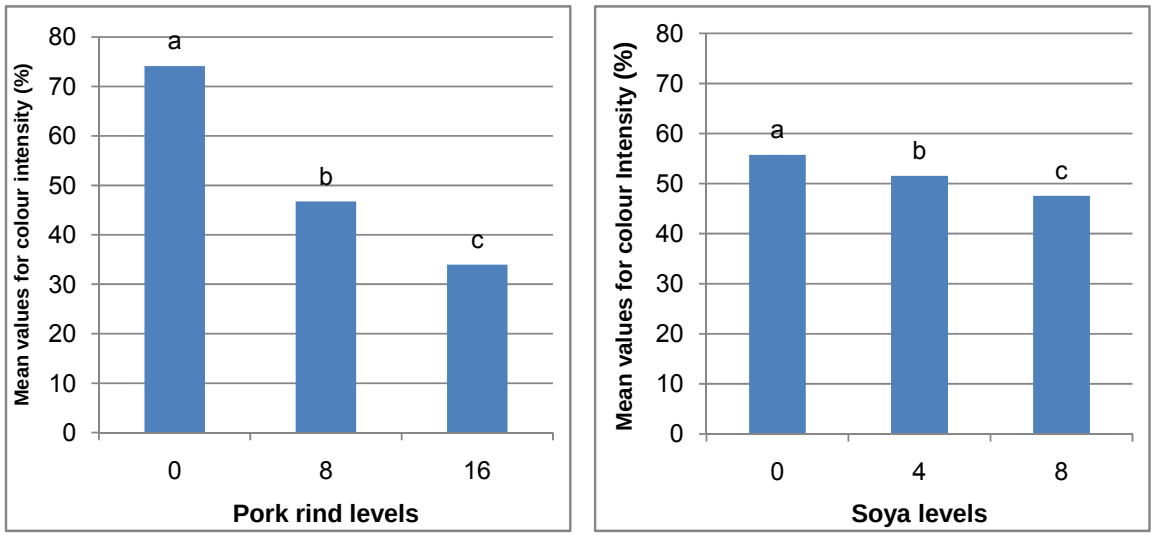
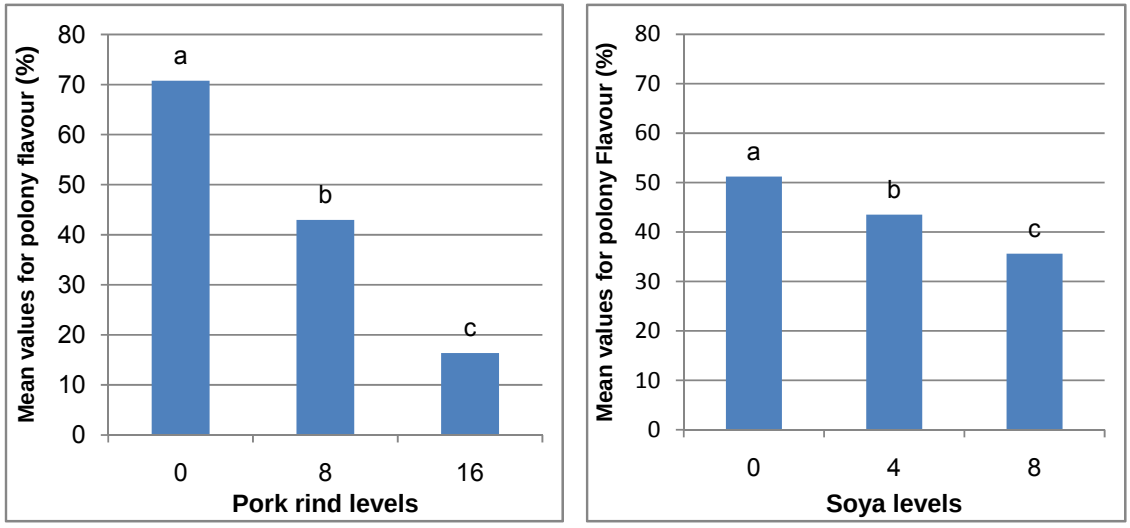


Figure 12 Mean scores for firmness, pasty and fatty mouthfeel of nine treatments of polony manufactured with three levels of pork rind (0, 8 & 16%) and soya (0, 4 & 8%). Means within each sensory attribute with the same letter do not differ significantly ($P > 0.05$).



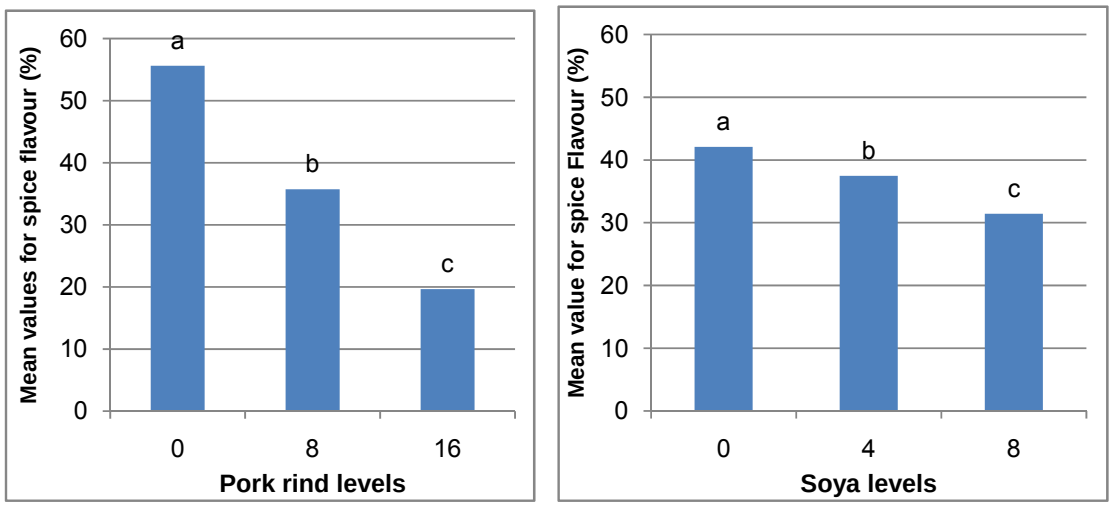
(a) (b)

Figure 13 Mean scores of the main effects of (a) pork rind on colour intensity and (b) soya protein on colour intensity, each with least significance difference [LSD ($P = 0.05$) = 5.09] statistically tested at 5%. Means with the same letter do not differ significantly ($P > 0.05$).



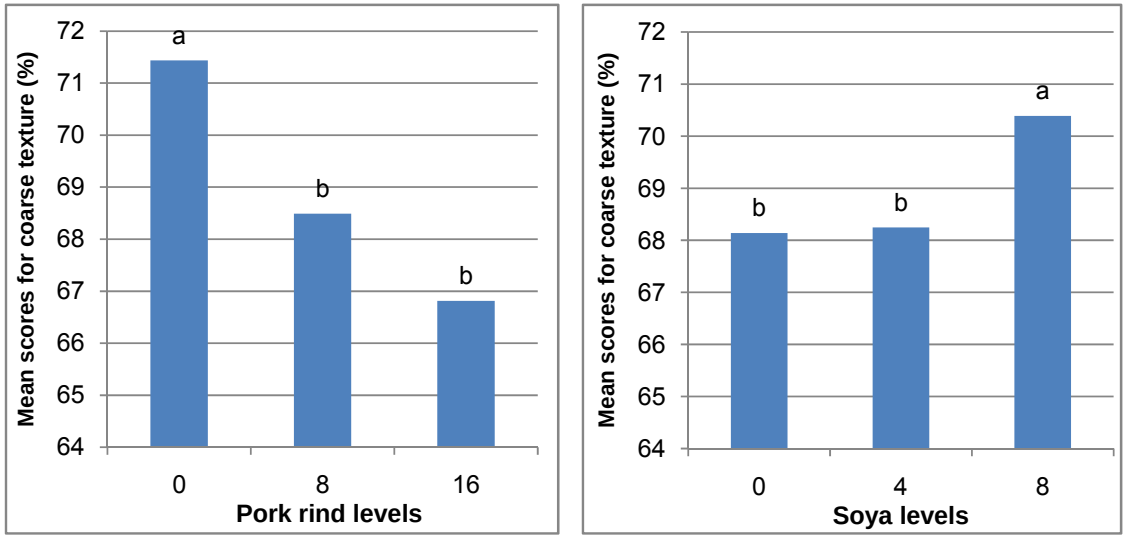
(a) (b)

Figure 14 Mean scores of the main effects of (a) pork rind on polony flavour and (b) soya protein on polony flavour, each with least significance difference [LSD (P = 0.05) = 5.61] statistically tested at 5%. Means with the same letter do not differ significantly (P > 0.05).



(a) (b)

Figure 15 Mean scores of the main effects of (a) pork rind on spice flavour and (b) soya protein on spice flavour, each with least significance difference [LSD (P = 0.05) = 2.06] statistically tested at 5%. Means with the same letter do not differ significantly (P > 0.05).



(a) (b)

Figure 16 Mean scores of the main effects of (a) pork rind on coarse texture and (b) soya protein on coarse texture, each with least significance difference [LSD (P = 0.05) = 3.46] statistically tested at 5%. Means with the same letter do not differ significantly (P > 0.05).

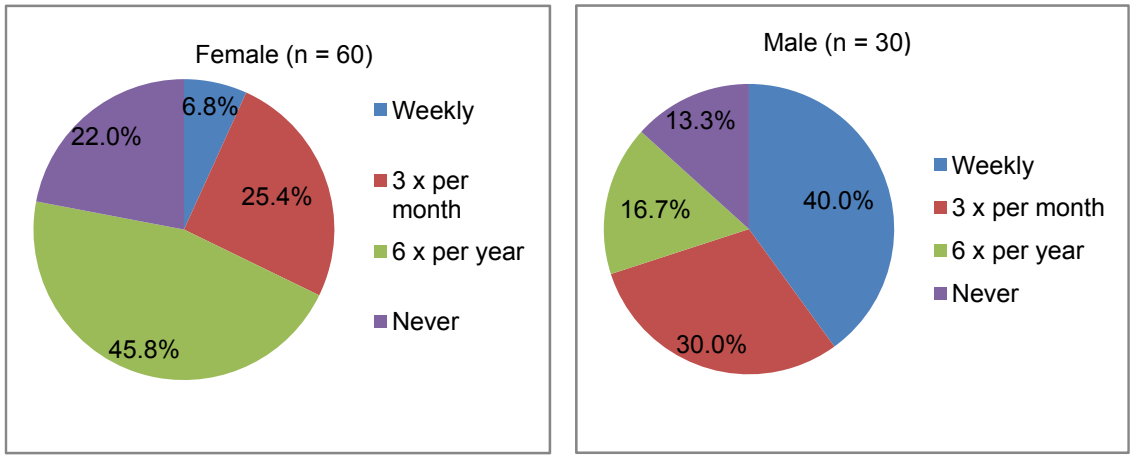
3.4. Consumer acceptability

The consumer results are presented in three sections: the socio-demographic information, sample preference and consumer degree of liking.

3.4.1. Socio-demographic information

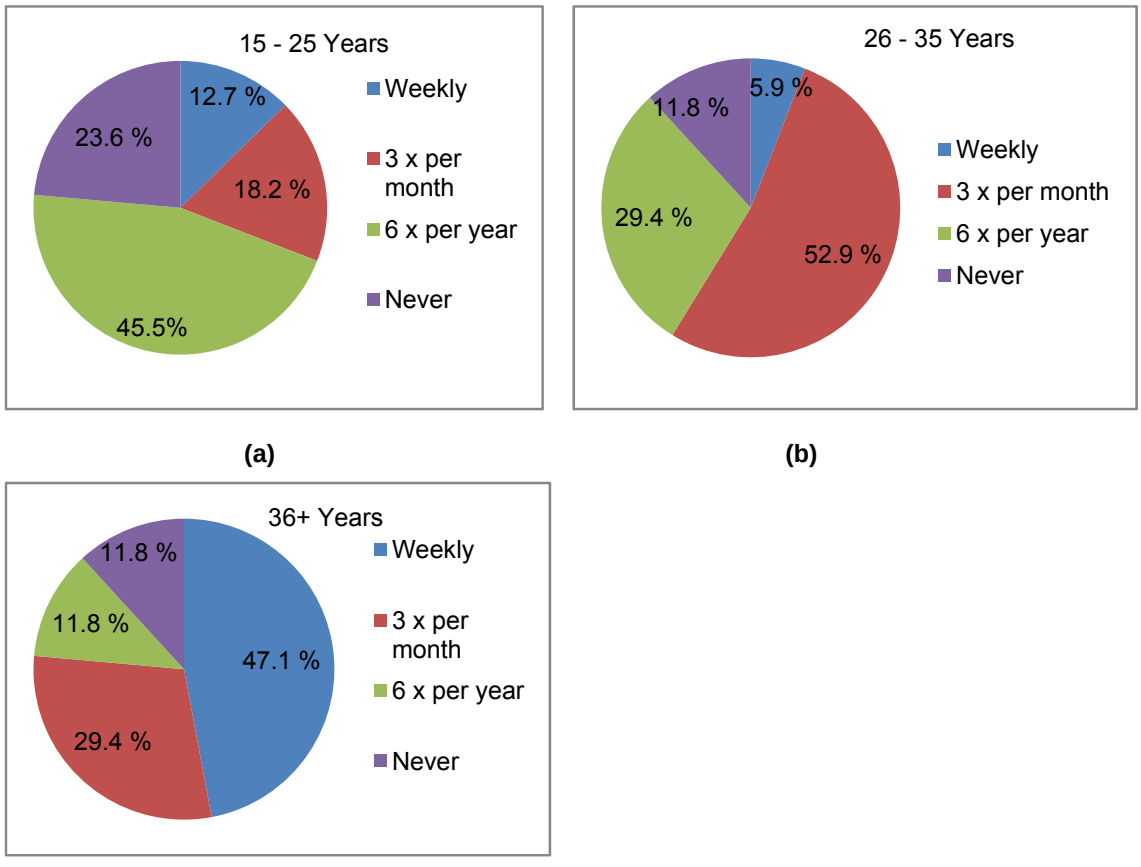
The socio-demographic information indicated that 40% of male consumers consume polony weekly, while only about 7% of females eat polony on a weekly basis (Figures 17 (a) and (b)). Another 30% of male consumers eat polony monthly as compared to 25.4% of female consumers. About 46% of females eat polony occasionally, compared to only about 17% of males. This information shows that males consume polony more frequently than females.

In Figures 18 (a), (b) and (c), the consumption pattern by age revealed that ≈ 47% of those aged 36 years and above consume more polony than those in the lower age groups. It was very difficult to explain why the consumption pattern differed. One would expect those in the age group of 26 to 35 years to eat more polony for convenience reasons. However, a possible reason could be that most of the consumers who assessed the polony were Food Science students at Stellenbosch University. They are familiar with the ingredients used for manufacturing commercial polony, and for quite a number of students the latter influenced their consumption of polony negatively.



(a) **(b)**

Figure 17 Number of **(a)** female consumers who assessed the five polony treatments and the frequency of polony consumption, and **(b)** male consumers who assessed the five polony treatments and the frequency of polony consumption.



(a) **(b)**

(c)

Figure 18 Frequency of polony consumption for **(a)** those in the age range of 15 – 25 years, **(b)** those in the range of 26 – 35 years, and **(c)** those aged 36 years and above.

3.4.2. Preference

Regarding preference, five treatments (R0S0, R0S4, R0S8, R8S0 and R8S4) were tested for degree of liking flavour and texture. The treatment which had no soya and pork rind protein (R0S0) was the most preferred for both flavour and texture, although sample R0S4 did not differ significantly from R0S0 for both flavour and texture (Figure 19). This result means that consumers preferred polony samples in which the MRM component was minimally or not replaced with soya (level of 0 to 4%). Samples for treatment R0S8, which contained 8% soya, were the least preferred for both flavour and texture, and differed ($P \leq 0.05$) from all other samples. This was because high levels of soya protein mask the flavour and result in poor texture. In samples where rind levels of 8% were added (R8S0 and R8S4), no difference ($P > 0.05$) was observed, i.e. both were liked moderately for their flavour and texture. In summary, one can assume that treatments in which moderate levels of soya and pork rind are used singly or in combination could have a reasonable market potential. However, it is quite clear that treatment R0S0 would have the highest market potential.

3.4.3. Consumer acceptability

Sample R0S0 was the most preferred for flavour and was also highly acceptable, while sample R0S8 was the least preferred and had an extremely low degree of acceptability for both flavour and texture (Figures 20 and 21). The other samples were intermediately preferred and liked for flavour and texture. This tendency of consumers to prefer or accept products in which no substitution of meat was made has been observed by other researchers. For instance, Abiola and Adegbaju (2001) found that the acceptability of pork sausages made from a batch with 0% rind was higher than those in which pork rind levels of 33, 66 and 100% were used.

3.5. Multivariate analyses of sensory, objective measurements and consumer liking

Multivariate analysis was conducted simultaneously on sensory, objective (instrumental and chemical) and consumer data to establish how the data was related. The methods used were principal component analysis (PCA) and the partial least square (PLS). In the next subsections, the PCA and PLS results are presented, including some correlation coefficients (r). It was further observed that correlation coefficients which were at least 0.670 (≥ 67%) were significant.

3.5.1. The PCA for sensory and objective results

A PCA was conducted to illustrate the association of the sensory and objective measurements for all nine treatments of polony (Figure 22). Correlations between sensory and objective measurements relevant to this study are presented in Tables 32 and 33. According to the PCA biplot (Figure 22), treatments R8S8, R16S0 and R16S4 were positively and strongly associated with raw batter pH, cohesiveness, white spots, protein in wet samples, lightness (L*), collagen and moisture. Among the latter attributes of polony, moisture (water) and collagen are responsible for change in other attributes. For instance, Fotjik and Mandigo (1998) noted that the addition of 10 and 20% pork skin (a high collagen raw material) to fresh sausages caused increased pH. A high pH in meat products usually results in greater WHC (Fotjik & Mandigo, 1998), which in turn affects variables such as colour, texture, firmness, juiciness and tenderness (Aberle *et al*., 2001). For that reason, it is not surprising to note that high collagen products of R16S0 and R16S4 are associated with raw batter pH, moisture, cohesiveness and lightness. Some attributes associated with R16S0 and R16S4 were

also correlated. For instance, L* was found to be positively and significantly correlated with moisture (P = 0.001, r = 0.897) and collagen (P = 0.004, r = 0.847), but was significantly and negatively correlated with fat (P = 0.018, r = -0.759; Table 33). It is also worth noting that treatment R8S8, which was found to be different from other samples due to its high protein content, is again seen to be associated with protein (Figure 22).

For treatments R0S0, R0S4 and R0S8, the attributes of coarseness, firmness, fat, WHC, ash, pink colour, colour intensity, redness (a*), garlic flavour, spicy flavour, polony flavour and salty taste were associated with the latter samples. However, sample R0S8 more associated with coarseness, WHC, a* and ash than with the latter flavours. The low association of flavour with R0S8 was due to the high soya content (8%) in R0S8, which masked the other flavours. The level of 8% soya also reduced redness, pink colour and colour intensity by the dilution effect (Matulis *et al*., 1995; Fotjik & Mandigo, 1998). Redness was positively correlated with pink colour (P = 0.020, r = 0.751), colour intensity (P = 0.013, r = 0.780) and coarseness (P = 0.013, r = 0.779), but was negatively correlated with collagen (P = 0.008, r = -0.808) (Tables 19 and 20).

Treatments R8S0 and R8S4 were positively associated with the characteristics of hardness, cohesiveness, sliceability at both 3 mm and 2 mm, raw batter pH, gumminess, fat, salty taste, firmness and polony pH (Figure 22). The strong association shows that moderate pork rind levels (8%), used alone or in combination with moderate soya levels (4%), have a strong influence on the sliceability, cohesiveness, hardness, gumminess, fat content, salty taste, firmness and pH of polony. The latter associations can further be substantiated by the correlations in Tables 20. Cohesiveness was found to be positively correlated with polony pH (P = 0.040, r = 0.689), sliceability at 3 mm (P = 0.023, r = 0.739) and sliceability at 2 mm (P = 0.022, r = 0.742). Gumminess was also positively correlated with polony pH (P = 0.016, r = 0.766), and sliceability at 3 mm (P = 0.014, r = 0.773) and at 2 mm (P =0.010, r = 0.796). These results illustrated that as the pH increased, gumminess, cohesiveness and sliceability increased. This indicates that higher pH has an influence on the textural properties of meat products. The reason for this is that the increase in pH values determines the amount of extracted meat proteins, which in turn determine the binding strength and texture of comminuted muscle products (Xiong & Kenny, 1999). In Tables 19 and 20, hardness was found to correlate positively with fat (P = 0.019, r = 0.755), but negatively with pasty texture (P = 0.038, r = -0.693). Morin *et al*. (2004) noted that fat positively contributes to the binding abilities of raw batter, which usually results in better texture attributes such as hardness.

Treatment R16S8 was highly and positively associated with fatty mouthfeel, pastiness, soya flavour, moisture and yellowness (b*). The positive relationship shows that, as moisture increased, pastiness and fatty mouthfeel (although these products actually were low in fat) also increased. The high level of soya (8%) increased soya flavour and possibly contributed to b*. This current observation of the association of soya protein with b* agrees with Cardoso *et al*. (2009). In their investigation, it was established that the addition of pea protein made the sausages more yellow. In Table 19, some attributes associated with R16S8 are further substantiated by correlation coefficients (r). Moisture was positively correlated with pasty texture (P < 0.0001, r = 0.972) and fatty mouthfeel (P < 0.0001, r = 0.978), but negatively correlated with pink colour (P < 0.0001, r = -0.976) and colour intensity (P < 0.0001, r = -0.975). The negative relationship of moisture to colour of sausages was reported by Fojtik and Mandigo (1998), who found that the use of high levels of water resulted in lighter coloured fresh sausages.

3.5.2. PLS for consumer, sensory and objective measures

The number of samples considered for the PLS was five in accordance with what was used for the consumer assessment. The sensory attributes of garlic flavour, spicy flavour, salt taste, polony flavour, firm texture, pink colour and colour intensity were the drivers for the consumers liking the flavour and texture of the polony, and the samples which were highly associated with flavour and texture liking were R0S0, R0S4 and R8S0, while sample R8S4 was not highly associated with consumer liking of the flavour and texture of the polony (Figure 23). Sample R0S8 was negatively associated with consumer liking of the flavour and texture. The flavour and texture of sample R0S8 were negatively liked by the consumers because it was associated with coarse texture and soya flavour.

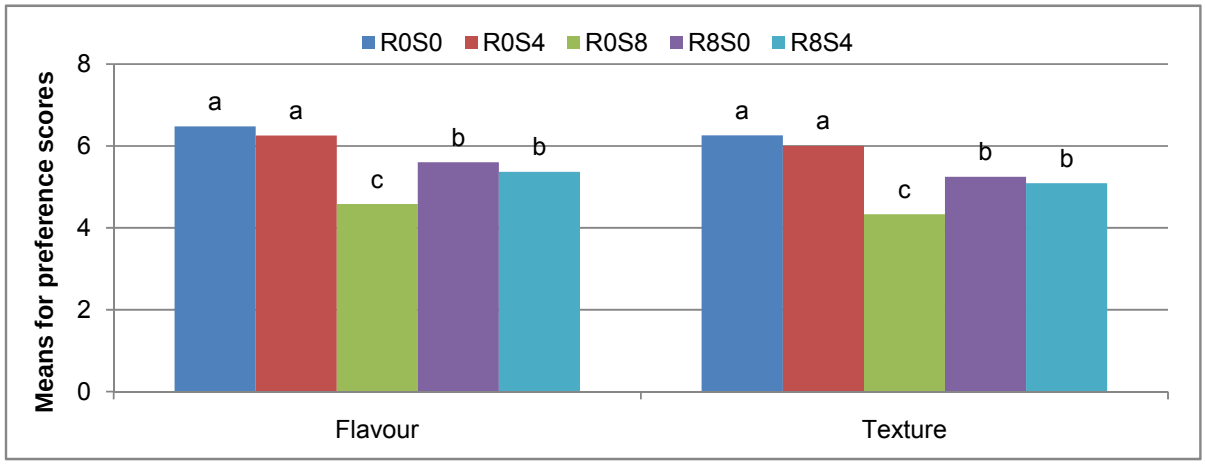


Figure 19 Consumer preferences for flavour and texture as indicated by 90 consumers, where R0S0 – 0% rind and 0% soya; R0S4 – 0% rind and 4% soya; R0S8 – 0% rind and 8% soya; R8S0 – 8% rind and 0% soya; R8S4 – 8% rind and 4% soya [Flavour LSD (P = 0.05) = 0.41 while Texture LSD (P = 0.05) = 0.42]. Means within each attribute with the same letter do not differ significantly (P > 0.05).

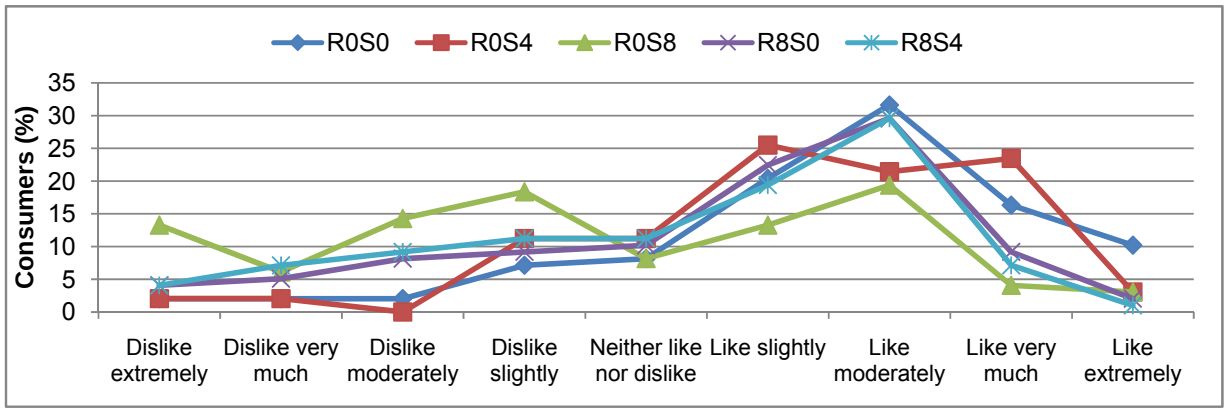


Figure 20 Percentage distribution of consumers using the nine classes of the hedonic scale for the flavour of the five polony samples.

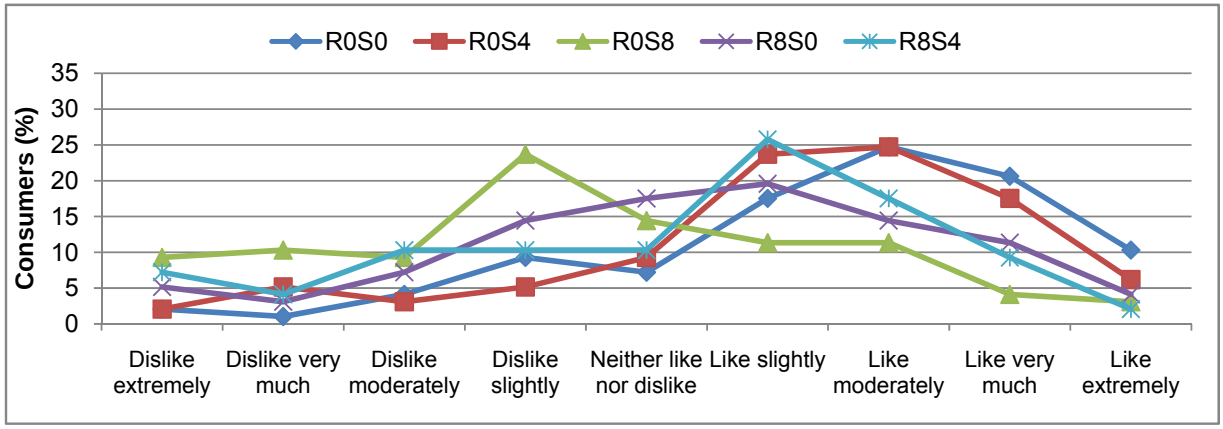
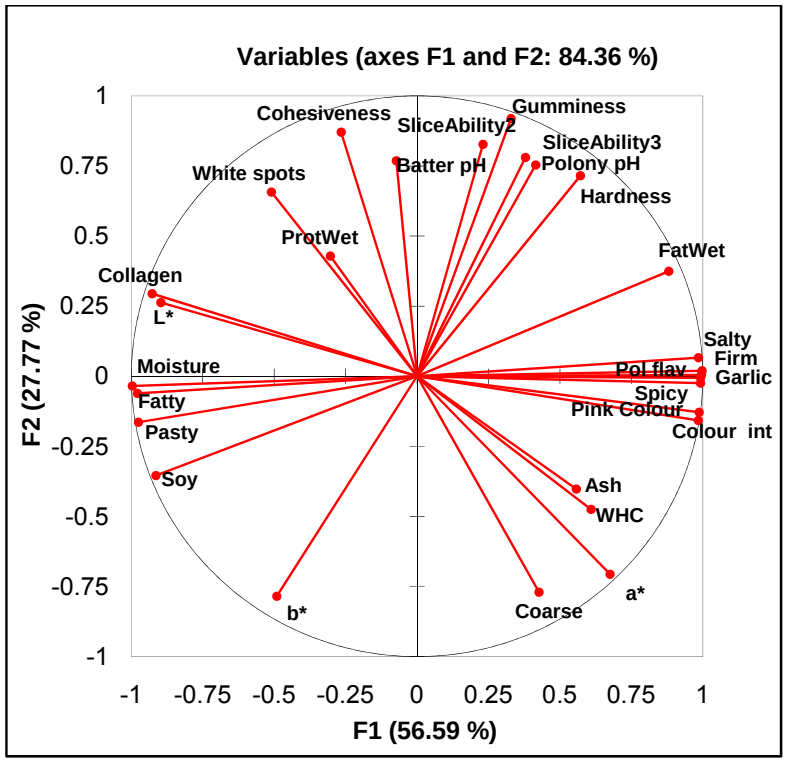
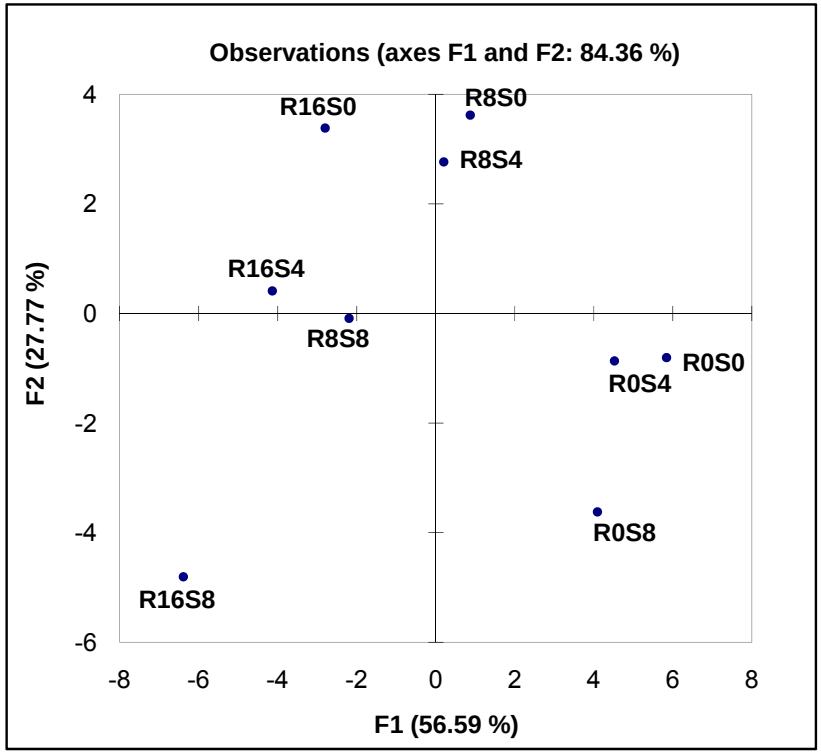


Figure 21 Percentage distribution of consumers using the nine classes of the hedonic scale for the texture of the five polony samples.



22 (a)



22 (b)

Figure 22 (a) PCA loadings plot of sensory attributes (pink colour, colour int = colour intensity, white spots, soy = soy flavour, pol flav = polony flavour, spicy = spicy flavour, garlic = garlic flavour, salty = salt taste, pasty, fatty = fatty mouthfeel and coarse) and objective measures (L* = lightness, a* = redness, b* = yellowness, WHC = water-holding capacity in square centimetres, ash = % ash, wet protein = % protein in wet samples, wet fat = % fat in wet samples, moisture = % moisture, collagen = collagen (mg/g), hardness = hardness (N), gumminess = gumminess (N), cohesiveness, batter pH = raw batter pH, polony pH, sliceability 3 = sliceability at 3 mm thickness, sliceability 2 = sliceability at 2 mm thickness) and **(b)** PCA scores plot for nine treatments of polony samples, where 83% is explained by factor 1 (56.35 %) and factor 2 (26.72 %) respectively.

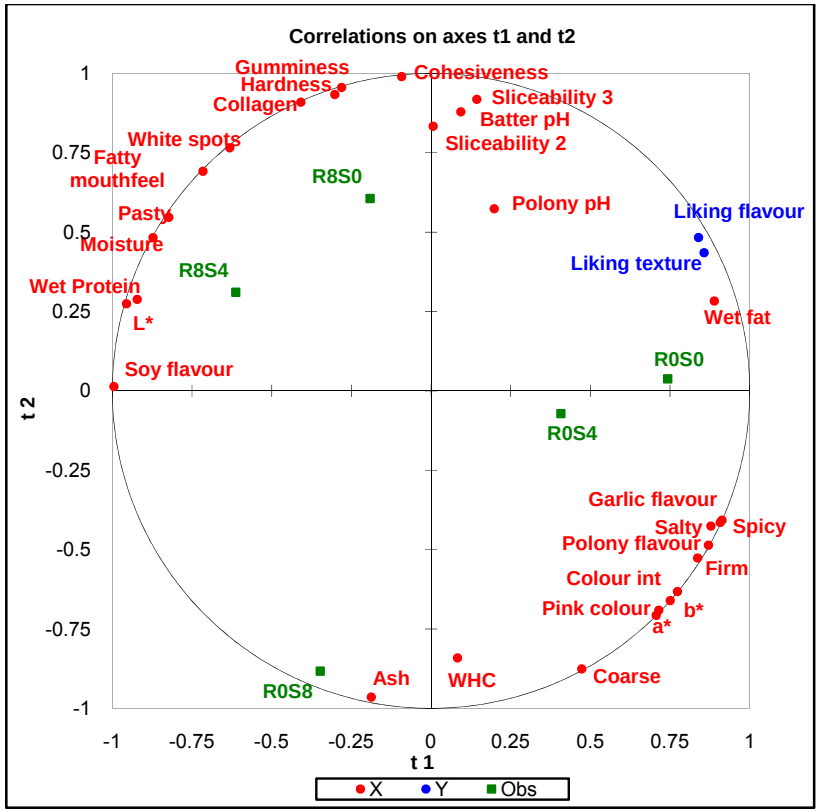


Figure 23 PLS of sensory, objective attributes and degree of liking flavour and texture in relation to five samples evaluated by consumers, where sliceability 2 = sliceability at 2 mm slice thickness, sliceability 3 = sliceability at 3 mm slice thickness, coarse = sensory coarse texture, WHC = water-holding capacity, wet fat = % fat in wet polony samples of polony, wet protein = % protein in wet polony samples, colour int = colour intensity, L* = lightness of polony samples, a* = redness of polony samples, b* = yellowness of polony samples, moisture = % moisture in polony samples, ash = % ash in polony samples and collagen = collagen in polony in mg/g.

Table 19 Correlation coefficients (r) between the physical and some sensory attributes of polony, with their significance levels (*P*).

	Pink colour		Colour intensity		Coarse		Firm		Pasty		Fatty mouthfeel	
	r	*P*	r	*P*	r	*P*	r	*P*	r	*P*	r	*P*
L*	-0.915	0.001	-0.934	0.000	-0.532	0.141	-0.891	0.001	0.801	0.009	0.831	0.006
a*	0.751	0.020	0.780	0.013	0.779	0.013	0.661	0.053	-0.531	0.142	-0.611	0.080
b*	-0.376	0.319	-0.376	0.356	0.441	0.234	-0.500	0.170	0.631	0.069	0.552	0.123
Hardness (N)	0.444	0.232	0.434	0.243	0.243	0.181	-0.588	0.096	-0.693	0.038	-0.639	0.064
Gumminess (N)	0.191	0.623	0.172	0.658	-0.662	0.052	0.347	0.360	-0.474	0.197	-0.390	0.300
Cohesiveness	-0.352	0.353	-0.383	0.309	-0.618	0.076	-0.251	0.515	0.154	0.693	0.255	0.508
Protein (%)	-0.357	0.346	-0.390	0.289	-0.473	0.199	-0.286	<0.456	0.116	0.766	0.138	0.723
Fat (%)	0.830	0.006	0.826	0.006	0.101	0.796	0.878	0.002	-0.894	0.001	-0.844	0.004
Moisture (%)	-0.976	<0.0001	-0.975	<0.0001	-0.388	0.302	-0.995	<0.0001	0.972	<0.0001	0.978	<0.0001
Ash (%)	0.587	0.096	0.572	0.108	0.589	0.095	0.552	0.123	-0.536	0.137	-0.625	0.072
Collagen (mg/g)	-0.948	<0.0001	-0.948	<0.0001	-0.618	0.076	-0.918	0.000	0.879	0.002	0.929	0.000
Sliceability (3 mm)	0.281	0.464	0.246	0.524	-0.282	0.463	0.391	0.298	-0.470	0.202	-0.405	0.280
Sliceability (2 mm)	0.110	0.779	0.081	0.837	-0.474	0.197	0.241	0.532	-0.334	0.532	-0.274	0.476
Polony pH	0.350	0.355	0.315	0.409	-0.224	0.562	0.430	0.248	-0.515	0.156	-0.408	0.276
WHC	0.663	0.052	0.664	0.051	0.738	0.023	0.569	0.110	-0.507	0.164	-0.551	0.124

WHC – water-holding capacity

Table 20 Correlation coefficients (r) between some physical and chemical attributes of polony, with their significance levels (*P*).

	Fat (%)		Moisture (%)		Protein (%)		Collagen (mg/g)		Polony pH		Sliceability (3mm)		Sliceability (2mm)	
	r	*P*	r	*P*	r	*P*	r	*P*	r	*P*	r	*P*	r	*P*
L*	-0.759	0.018	0.897	0.001	0.569	0.110	0.847	0.004	-0.116	0.766	-0.102	0.794	-0.013	0.974
a*	0.364	0.335	-0.657	0.054	-0.588	0.096	-0.808	0.008	-0.299	0.435	-0.330	0.386	-0.428	0.250
b*	-0.697	0.037	0.512	0.159	-0.239	0.535	0.260	0.500	-0.792	0.011	-0.723	0.028	-0.669	0.049
Hardness(N)	0.755	0.019	-0.602	0.086	0.136	0.726	-0.328	0.388	0.637	0.065	0.638	0.064	0.655	0.056
Gumminess(N)	0.633	0.067	-0.366	0.333	0.251	0.515	-0.031	0.936	0.766	0.016	0.773	0.014	0.796	0.010
Cohesiveness	0.119	0.760	0.231	0.549	0.329	0.387	0.530	0.142	0.689	0.040	0.739	0.023	0.742	0.022
Sliceability (3mm)	0.580	0.102	-0.413	0.269	0.211	0.585	-0.139	0.721	0.822	0.007	1	0.000	0.928	0.000
Sliceability (2mm)	0.468	0.203	-0.269	0.484	0.309	0.419	0.022	0.955	0.630	0.069	0.928	0.000	1	0.000
Polony pH	0.677	0.045	-0.431	0.246	0.102	0.793	-0.149	0.703	1	0.000	0.822	0.007	0.630	0.069
WHC	0.342	0.367	-0.579	0.103	-0.355	0.349	-0.735	0.024	-0.103	0.791	-0.072	0.855	-0.171	0.660

WHC – water-holding capacity

4. CONCLUSION

This study investigated the effect of replacing MRM with pork rind and soya flour protein on the physical (chemical and instrumental) and sensory characteristics of nine polony treatments. The effect on consumer acceptability was also considered. It was observed that the replacement of MRM with higher levels of pork rind (16%) and soya flour (4 and 8%) resulted in polony treatments which were very light in colour, poor in texture and flavour while those with lower levels of rind (≤8%) and soya (≤4%), including the control, had better texture, colour and flavour. The results also indicated that the treatments with lower levels of rind and soya, including the control, were more acceptable than those with higher levels of the latter protein additives.

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CHAPTER 5

GENERAL DISCUSSION AND CONCLUSION

The formulation of low-cost meat products, polony inclusive, is extremely important in countries with poorer communities. In such countries the majority of people cannot afford to buy meat and its products regularly, as these products are expensive (Whitney & Rolfes, 1999). For instance, in South Africa, although it is an upper-middle-income country, poverty is widely acknowledged as being among the most serious problems the country is facing (Agbola, 2003). As a result of these problems (poverty and lack of affordability), some researchers have been looking for ways of making meat protein more affordable. Yetim *et al*. (2001) suggested the use of non-meat ingredients in fresh and emulsion-type meat products. However, the use of non-meat materials could have a good or negative influence on the attributes of meat products. The current study focused on making polony using chicken mechanically recovered meat (MRM) as the main protein source. Soya and pork rind proteins (both higher in protein content than MRM) were used to partially replace chicken MRM in some treatments, with a view to making polony cost effective while maintaining 10% protein content in the end product. The number of polony treatments which were made by combining three levels of pork rind (0, 8 and 16%) and three levels of soya (0, 4 and 8%) were nine (R0S0, R0S4, R0S8, R8S0, R8S4, R8S8, R16S0, R16S4 and R16S8, where R stands for pork rind and S for soya flour). The treatment to which no rind and soya were added was used as a control (R0S0). The effects of replacing MRM on the chemical, physical and sensory characteristics of polony were also investigated.

The major chemical effects which were observed in treatments to which pork rind, soya flour or both were added were the general increase in moisture and collagen, and a reduction in the fat content of the polony samples compared to the control. The control was the treatment to which neither soya nor rind were added (R0S0). The increase in moisture was caused by an increased addition of water and rind to replace MRM. The control had the least added water, while the ninth treatment, that is the treatment in which MRM was replaced with 16% rind and 8% soya (R16S8), had the most added rind and water. As expected, the fat content reduced because the chicken MRM, which was analytically found to contain the highest amount of fat, was being reduced from the control up to treatment nine. As for the collagen, its increase in some treatments (R8S0, R8S4, R8S8, R16S0, R16S4 and R16S8) is attributed to the use of a high-collagen raw material (rind). The consequential effects of reducing MRM by adding more water, rind and soya manifested in increased lightness (L*) and decreased redness (a*) when compared to the control. The effect was also observed in the general increase of hardness, gumminess and cohesiveness in samples with 0 and 4% soy flour, and this effect was noted up to the level of 8% pork rind. The increase of rind up to 16% reduced hardness and gumminess. Cohesiveness only reduced in the sample with 8% soya and 16% rind (R16S8). The binding properties of all the treatments, as measured by the water-holding capacity (WHC), was 0 cm^2 for treatments with good WHC, while treatments R0S0 and R0S8 exhibited poor WHC.

As for the sensory results, the major effects of combining soya flour and pork rind or their single use in replacing MRM were seen in decreased pink colour, colour intensity, salty taste, garlic flavour, polony flavour, spicy flavour and firmness, while soya flavour, pasty texture and fatty mouth-feel increased. The negative effect of MRM replacement on the colour of polony can be rectified by adding more pro-colour additives in the formulation of polony. Examples of such additives are dyes (such as erythrosine and annatto). Erythrosine can be added up to 30 mg/kg (Department of Health, 1996). The taste of salt can be

improved by adding more salt, but care must be taken not to add too much salt because consumers may not desire polony which is too salty. Normally, 2% salt is recommended (Feiner, 2006). Garlic, polony and spicy flavour can be enhanced by increasing the spices affecting the respective flavours. The increase in spices also helps to reduce the soya flavour. Alternatively, the undesirable soya flavour can be minimised by using less soya flour. In the current study, soya flavour was very high in products with 8% soya flour. This level can be reduced to 4% or less, because consumers still liked such products. For instance, the degree of liking flavour for R8S4 was 57.1%. The reduction in soya flour not only reduces the soya flavour, but also improves firmness, pastiness and fatty mouthfeel. However, the latter textural attributes can be improved further by using hydrocolloids such as carrageenan, alginate, guar gum and locust bean gum. Carrageenan, for example, improves moisture retention, slicing properties, mouthfeel and theh WHC of processed meat products (Imeson, 2000; Zou *et al*., 2010). The use of hydrocolloids is permitted in South Africa up to 3 000 mg/kg (Department of Health, 1987). However, it must be noted that the increase of ingredients or the use of other ingredients to improve the polony attributes inevitably increases the cost of production. For the current study, it was found that the control treatment was the most expensive because it had the highest MRM used, while the ninth treatment (R16S8) was the cheapest because less MRM was used to make it. However, even if R16S8 was the cheapest combination, it was found to be the poorest in terms of sensory attributes, as was revealed by the low scores of the trained panel. These findings demonstrate that the optimal utilisation of pork rind and soya lies in moderate combinations, at the most 8% rind and 4% soya flour.

Although most sausage products in supermarkets and some regulations in South Africa show that replacement of meat is regularly practised in the South African meat industries, little scientific research has been published on this practise in South Africa. It is hoped that the current study will be used by the meat industry as a reference material and thus help to open up more documented research in the use of meat replacers both in the industry and academic institutions in South Africa.

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ANNEXURE 1

QUESTIONNAIRE: ACCEPTABILITY OF POLONY

NAME OF JUDGE:_____ **JUDGE NO:**_____

Please (CIRCLE) whichever is applicable	Gender: Male / Female	Age: 15-25/ 26-35/36-45/46+	Consumption of polony: Weekly / 3x per month or less / Approx 6 times a year / Never

INSTRUCTIONS

- PLEASE TASTE SAMPLES FROM **LEFT TO RIGHT**. RINSE YOUR MOUTH WITH WATER BEFORE BEGINNING AND BETWEEN THE SAMPLES
- TAKE A GENEROUS BITE FROM EACH SAMPLE. RANK THE SAMPLES FOR DEGREE OF LIKING. IN EACH CASE, CIRCLE THE NUMBER NEXT TO THE PREFERRED ANSWER.

How do you like the **FLAVOUR** of polony?	CODE		CODE		CODE		CODE		CODE	
	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely
	8	Like very much	8	Like very much	8	Like very much	8	Like very much	8	Like very much
	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately
	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly
	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike
	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much
	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

How do you like the **TEXTURE** of polony?	CODE		CODE		CODE		CODE		CODE	
	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely
	8	Like very much	8	Like very much	8	Like very much	8	Like very much	8	Like very much
	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately
	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly
	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike
	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much
	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

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